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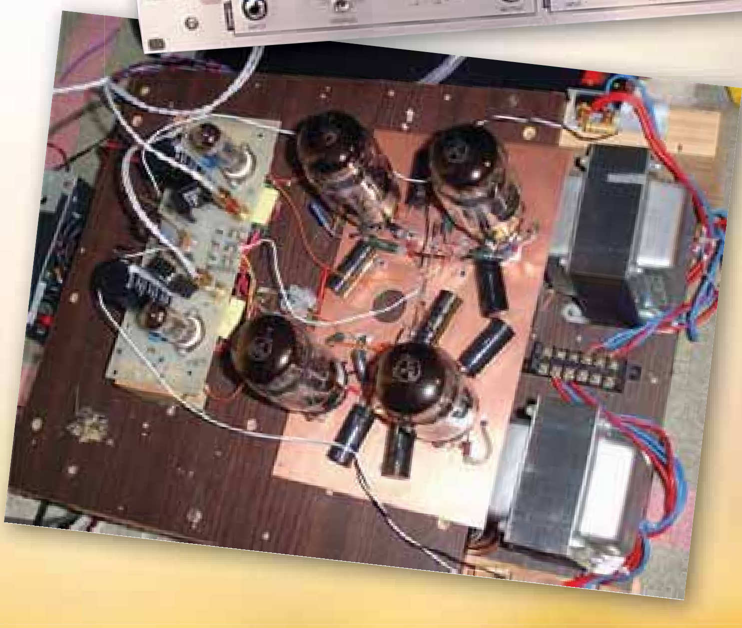

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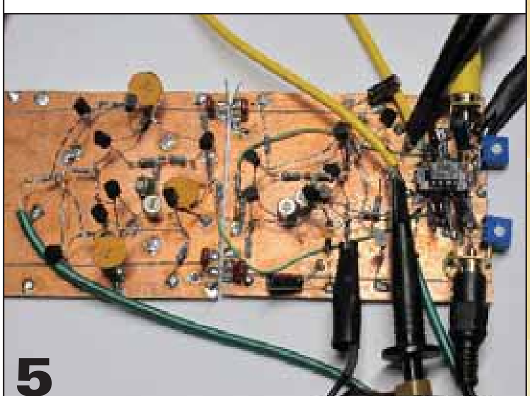
CONTENTS

VOLUME 41 NUMBER 8 AUGUST 2010

"The peculiar evil of silencing the expression of an opinion is, that it is robbing the human race; posterity as well as the existing generation; those who dissent from the opinion, still more than those who hold it." — JOHN STUART MILL

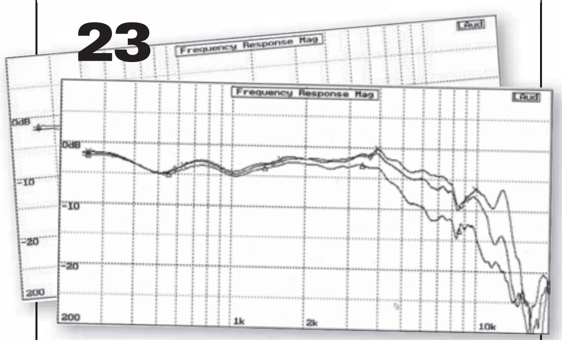
FEATURES



5

DEPARTMENTS

23



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CES 2010—CHANGES ABOUND

By David Weinberg

OPPO BDP-83 BLU-RAY DISC PLAYER

Putting this player through its paces.

By Gary Galo

SIGNAL CURRENT LOOPS & POWER SUPPLY INTERACTION

Sometimes, tubes can use a little solid-state help.

By Richard Sears

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audioXpress (US ISSN 1548-6028) is published monthly, at $50.00 per year. Canada, add $12 per year; overseas rates $85.00 per year; by Audio Amateur Inc., Edward T. Dell, Jr., President, at 305 Union St., PO Box 876, Peterborough, NH 03458-0876. Periodicals postage paid at Peterborough, NH, and additional mailing offices.

POSTMASTER: Send address changes to: ***audioXpress***, PO Box 876, Peterborough, NH 03458-0876.

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Printed in the USA.

The Metz Preamp

This full-featured preamp design includes source switching, digitally controlled volume, and low-noise/low-distortion for high-quality performance.

The design aspect of my audiophile hobby has been dominated by power amplifiers, starting out with tubes back in high school and progressing to a variety of FET designs. One idea in the back of my mind for a long time was to design a preamp, but somehow I always made do with a receiver as the source selector and control center for my system. For the last ten years, though, the ol' Sherwood receiver has been apart at least three times to nurse dirty controls and switches, and it had always left some nagging doubts about the ultimate quality of its sonic performance. The time had come to tackle the preamp.

KEY GOALS

As I set out on this design, I began with a set of goals. First and foremost, I am both a serious amateur audiophile in pursuit of performance and an engineering pragmatist. I wanted a straightforward stereo source selector, monitor selector, volume control, and line amp, and not much more. This is not a home entertainment center/surround sound/video switcher/MP3/espresso machine—just good clean stereo. I wanted to achieve the following:

- Clean, long life, reliable source switching
- Electronically controlled, non-deteriorating volume control
- Impeccable sonic performance and low noise and crosstalk

My design includes the following features:

- Eight inputs—MM phono, Tuner, CD1, CD2, Tape1, Tape2, Aux1, Aux2
- Four record outputs with monitor select for CD2, Tape1, Tape2, Aux1
- Gold dual contact sealed relay source selection
- Front panel headphone output
- Front panel 1/8″ appearance of Aux1, for an iPod or similar device
- Optical encoder volume/balance control
- PIC microprocessor control
- Bypass-able bass and treble controls
- Mute
- Two sets of controlled outputs to amplifiers
- Ground plane main/audio PCB for low noise and crosstalk
- Two power switched 5V outputs to drive relay-controlled power strips for system components

DESIGN CONSIDERATIONS

Beyond these features, there were three key design considerations. The first was the method of input selection—can I do this entirely solid-state? Short and simple, based on distortion performance and crosstalk, the answer is no.

I researched all the available analog switches, including those meant for high-end audio applications, as well as do-it-yourself discrete FET solutions, and nothing is adequate as far as crosstalk is concerned, primarily due to semiconductor parasitic capacitances. They also introduce a small amount of distortion due to R_{ds}sat modulation. The next best, mechanical alternative was sealed relays. After an extensive search, I chose the Panasonic AGQ200 series, the 12V variety requiring relatively low coil currents, and featuring gold-plated bifurcated contacts. These should provide a life expectancy well in excess of most of us!

Second was the volume control—definitely not a potentiometer, and resistor ladder networks still involve mechanical contacts. I chose an optical encoder in conjunction with the highly respected Burr-Brown designed TI PGA2310 volume control chip. Given the cost of an optical encoder, and the desire for simplicity, I then decided to combine the volume and balance functions in one control, with a button to select between them, and LEDs to indicate the settings. Of course, once you choose the digital volume control, you already have one foot firmly stuck in the mud of the op amp/discrete design debate, which brings us to the third key design decision.

Op amps versus discrete. Like a good audiophile snob, I began this project firmly and faithfully committed to a discrete FET amplifier design approach, and scratched out multiple pages of J74- and K175–based phono and line stages, and prototyped them. They all worked quite nicely. (I'm sure some of you think it should have been 12AX7s!)

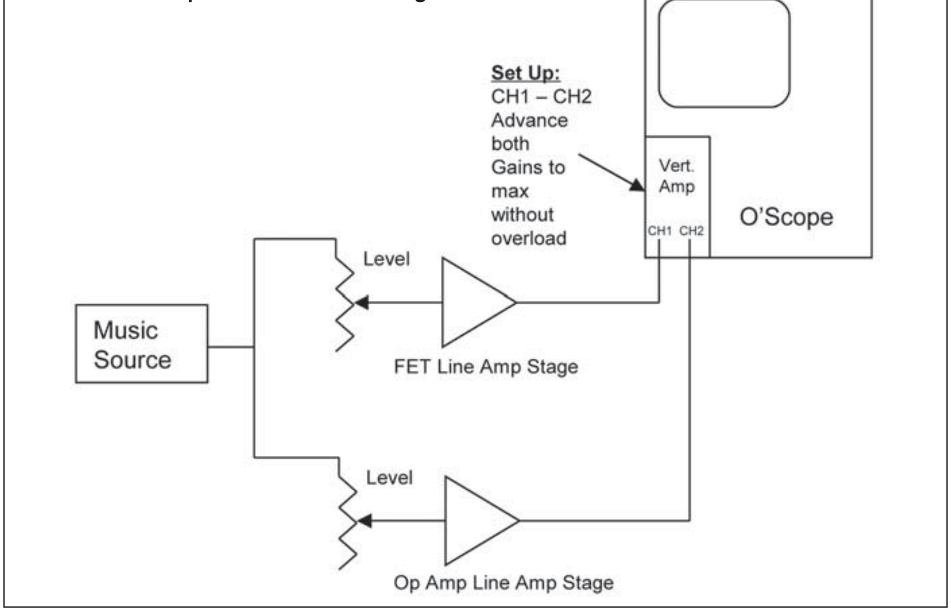
When I looked at PCB layout and put together a parts list, I realized what a load of discrete parts! What a forest this board is going to be! I decided to have a bake-off with an op amp alternative, especially because I already had working discrete FET prototypes. I went ahead and designed OPA2134-based phono and line stage alternatives, and ran them side by side with the FET prototypes. That raised the question of what kinds of tests to run.

The first were standard THD measurements, with results in **Table 1**. While these look great for both designs, they don't address dynamic performance, and I knew this was just not going to be sufficient in the world of discrete versus op amp mythology and never-ending controversy.

TABLE 1: THD TESTS OF OPA2134 STAGE, %THD VS. OUTPUT VOLTAGE FOR FET AND OP AMP STAGE

Output V>	150mV RMS		1V RMS		2.5V RMS	
	1kHz	10kHz	1kHz	10kHz	1kHz	10kHz
FET	.0009	.0026	.0005	.0025	.0007	.002
op amp	.0012	.0029	.00045	.0019	.00025	.0012

FIGURE 1: Comparison test block diagram.



From here, you can dive into IM, TIM, and various other esoteric measurements, but I wanted a more dynamic and convincing test, something that would resonate more with the ethereal golden ears hyperbolic comparative world, so I came up with the following (**Fig. 1, Photo 1**):

1. Assume the discrete FET designs are golden—the standard of comparison—after all, they were adaptations of Borbely preamp/line stages that have appeared in print here. In any case, many consider and accept them as the "best effort" approach.

2. Arrange the FET designs to be run in parallel with the op amp designs, fed by a common source, and provided with a precision input attenuation and output level matching capability.

3. Feed the common input with real, dynamic, and varied music source material, not static signals.

4. I fed the level matched outputs to my best Tektronix 2 channel oscilloscope amplifier, with one channel in the invert mode, and both in add mode, so that any amplitude or phase difference between the two inputs would show up clearly on the screen.

5. Turn the scope amplifier channel gains up to the highest level they will handle without distortion or overload. I used a 7A26 plug-in on my 7904A scope, and this point was roughly at a gain of 80dB, which would make differential artifacts visible down to at least –90dB (~ 1/10 division). This can be done because the outstanding design of the 7B26 plug-in performs the invert/add functions far enough to the front end of the amplifiers that much of the gain appears after the subtraction. If you don't believe this works, try it, and you will be amazed. It takes some effort to match the channel gains to get a null, and when they are slightly off, all that gain applied to a real difference will im-

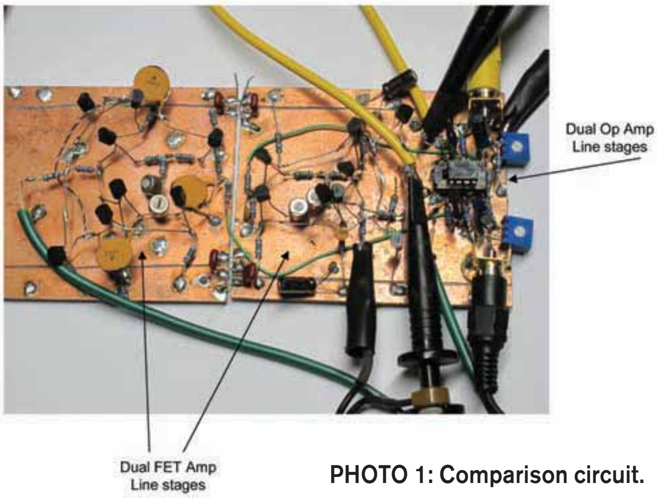


PHOTO 1: Comparison circuit.

mediately make the scope display go off the screen!

6. The result is a flat line if both input signals are identical, with any difference in the two showing up as blips or trace deviations on the otherwise flat scope trace.

7. In addition to just looking at it (where you might miss something temporally), use the adjustable scope trigger level to "catch" any deviations between the two signals within, say, > -90dB.

8. The final result? For the test comparison between the discrete FET line amp stage and the OPA2134 version, there was no discernible difference in output signals, for all the different music inputs tested, within a discernible amplitude of -90dB below the input levels. In other words, they produced—within a negligible error band—exactly the same output for the same input.

The unavoidable conclusion is that the op amp stages perform as well as the discrete FET alternatives, with real dynamic music signals, and greatly simplify the design. To seal the deal, I put the two prototype line amps in my system, between the CD player and amplifiers, with an A-B switch. The result, again, was that both sounded excellent, and indistinguishable.

The only thing left to do was to come to grips with the results and go ahead with the project!

OVERVIEW

Figure 2 is a block diagram of the preamp. One of eight inputs is selected by a relay network. The phono input passes through the phono amp stage first to apply RIAA compensation and to bring it essentially to the same level as the other line level inputs. Four of the inputs also appear at the monitor select relays.

The left and right selector relay outputs may be bridged for mono by the mono relay, while the signals at this point are also fed to a pair of line buffers for the four record outputs. Following this, the main/monitor relay selects the signal to be passed on from the main inputs of the monitor selection. A pair of buffers feed the volume control chips, which are followed by the bypass-able tone controls. This, then, is also the controlled amplifier output. The pair of headphone amplifiers are also driven from this point.

The center of control is a PIC 16F877A microcontroller, which receives all of the switch inputs and the optical encoder input as parallel I/O, and controls LEDs, the volume control chip, and relay drive chips via an SPI serial interface. Power is provided by a toroidal transformer, accepting 120 or 240V input, and providing regulated ±15V for the analog circuits, and +12 and +5 for the digital circuits, with separate grounds.

DETAILED DESIGN

Input and monitor selection is performed by a set of 8 and 5, respectively, Panasonic AGQ20012 relays (**Fig. 3**). I chose these on the basis of their 1) small size, 2) low coil current requirement, 3) low resistance, gold-plated contacts, and 4) "duplex" bifurcated contacts, to ensure a long noise-free operating life. The same relays are used throughout for the Mono/Stereo, Monitor/Main, and tone control bypass switches.

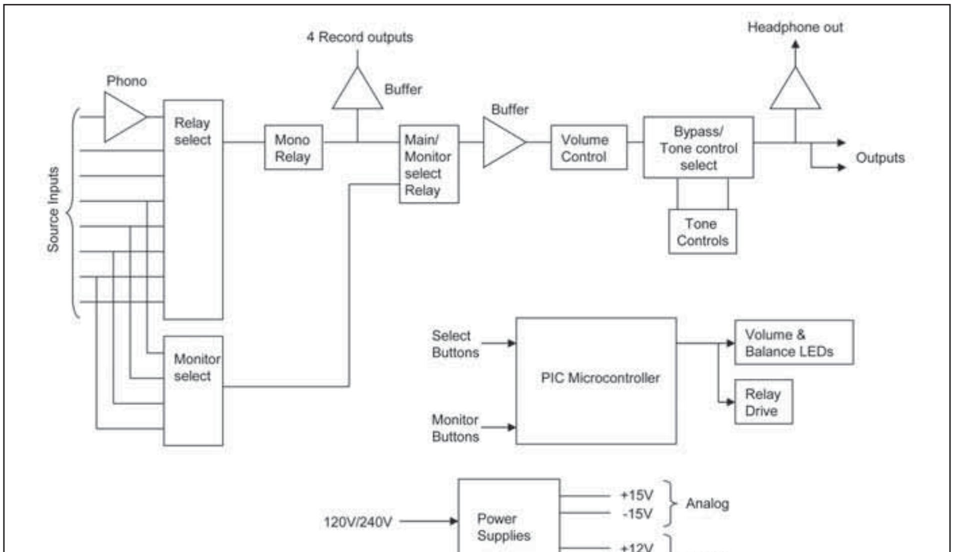


FIGURE 2: Preamp block diagram.

All the relay coils are driven by a pair of Alegra A6821 SPI serial input parallel I/O drivers, U3 and U4—very convenient devices! All control push buttons are lighted with LEDs, which, in the case of those associated with relay functions, are also energized by the relay drivers.

The phono preamp (**Fig. 4**) is the MM type, because I have no MC equipment. The MM design consists of a low impedance buffer stage driving a passive high-frequency rolloff, R5 and C4, followed by an active low-frequency boost stage, providing standard RIAA compensation.

The record output buffer as well as the volume control chip input buffer are both simple ×2 gain stages (**Fig. 5**). Both are preceded with 75kHz low-pass and 10Hz high-pass filters, to remove low- and high-frequency input noise. The volume control chip requires a source impedance < 600Ω to meet its distortion specs—therefore, the buffer.

SPI serial input also controls the TI/

Burr-Brown PGA2310 volume chip. More on how this is functionally used later, in the firmware section. Mute capability is also provided by the PGA2310.

Output from the volume control goes to the pair of amplifier drive outputs, via the tone control bypass relay, which is normally in the bypass mode. The bass and treble tone control stage consists of a buffer, driving a double feedback loop Baxandall ±10dB boost/cut stage, with a 1kHz rollover frequency (**Fig. 6**).

An op amp/FET power stage (**Fig. 7**) drives the headphone output, and is capable of providing several watts to speaker

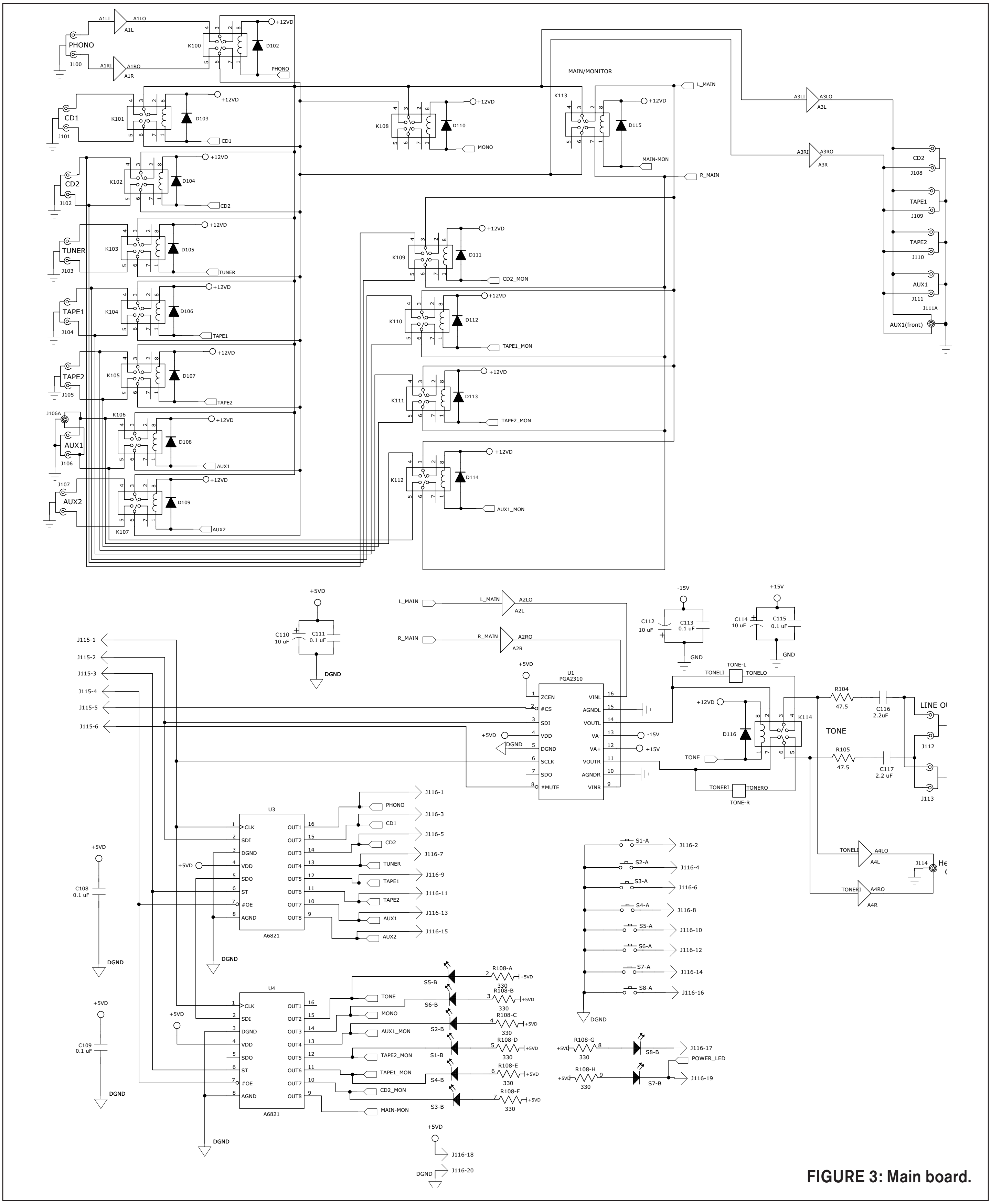


FIGURE 3: Main board.

impedance loads, if desired. The power stage includes a bias adjustment, which you must perform as part of initial unit testing.

The controller (**Fig. 8**) is a PIC 16F877A, with internal program and user flash memory and SPI serial control. Select, monitor, and other push button inputs appear directly as parallel I/O. The optical encoder connects as a two-bit input. Volume position is indicated by a set of 24 LEDs arrayed around the encoder, while balance is depicted by a linear 4 + 4 left/right green/red LED display (**Fig. 9**). The firmware is described later, and is available for download, or programmed into a chip, as shown in the parts list.

An Avel Lindberg toroidal power transformer feeds a pair of adjustable series regulators set for ±15V for the analog circuits, while the digital supplies are generated by fixed +5 and +12V regulators (**Fig. 10**). Adjustables are used for the analog supplies because they are quieter than the fixed variety. Grounds for the analog and digital supplies are kept separate, except for a single, well-chosen tie point, under the volume control chip. The power transformer provides windings for only one set of outputs. Add the digital supply windings to the transformer as described in the assembly guidelines.

When the preamp is plugged in, the power supplies and the controller are always on, and the power on/off function (power button) turns on the analog operation. In the off mode, all relays, and therefore input selects, are de-energized, and the volume is muted. In the on mode, input selections are recalled from EEPROM and applied, but volume always starts off at zero. The design includes a pair of power on/off controlled +5V outputs, which can control power to other

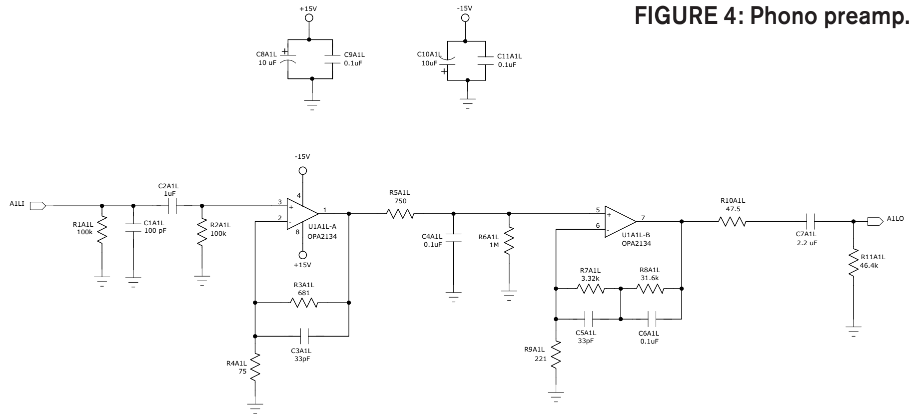


FIGURE 4: Phono preamp.

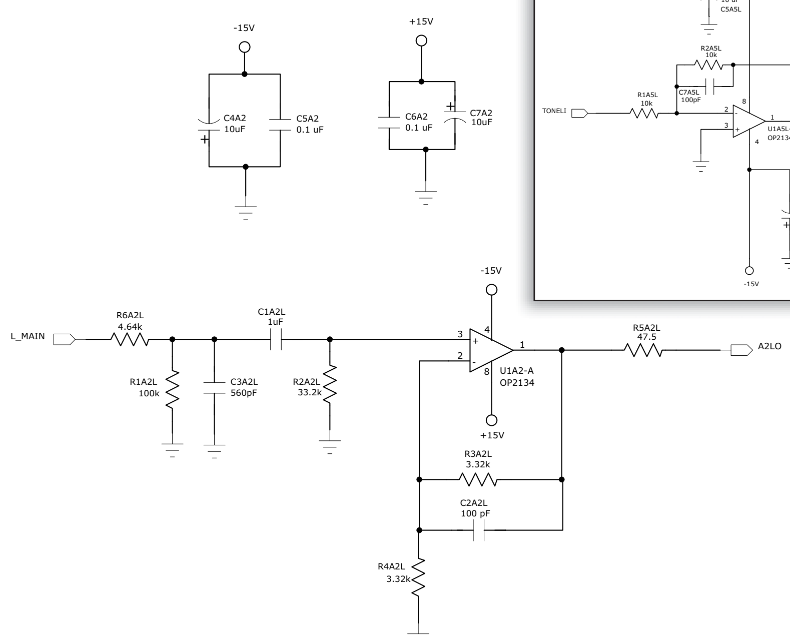


FIGURE 5: Gain stages (4 on the main board).

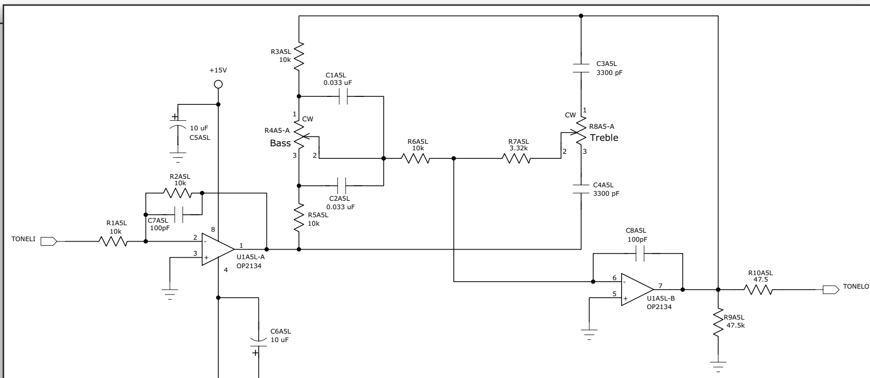


FIGURE 6: Tone control stage (2× on the main board).

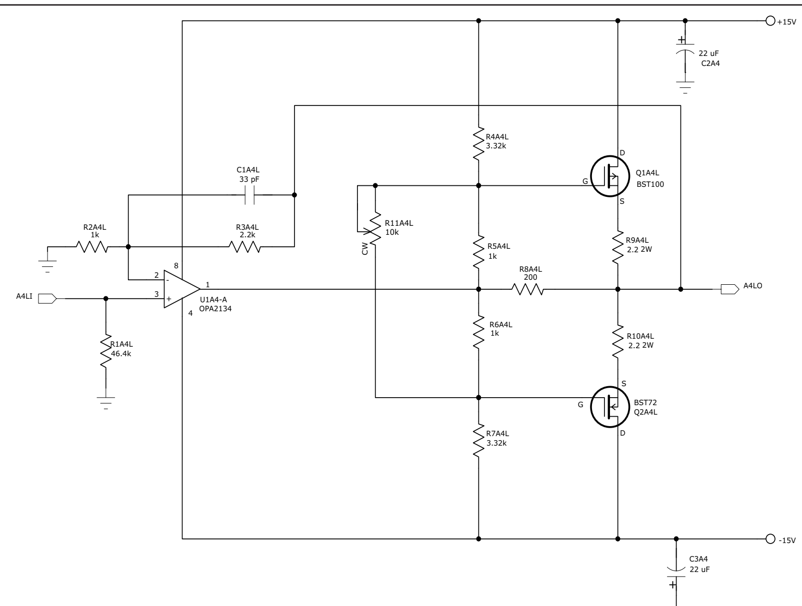


FIGURE 7: Head phone output stage (2× on the main board).

system components. In my case, I added a relay to a power strip, into which my amps, CD players, and so on, are plugged, so the whole system comes up together. There is no need to flip an array of switches!

PCB PARTITION AND DESIGN

Circuitry is distributed over three boards. The main board houses all the analog circuitry, some of the control switches, and the very convenient Kobicon dual gold-plated RCA input and output jacks. The key features of the design here are a multilayer board that includes ground plane under analog signals, and very careful layout and power distribution to minimize crosstalk and noise.

The controller and input select switches are on the second board, a partition I chose for convenient physical layout of the switches and to keep the digital functionality separate. Finally, you mount the optical encoder and associated volume and balance indicating LEDs and their serial to parallel drive chips on a separate board, again to facilitate the mechanical design and mini-

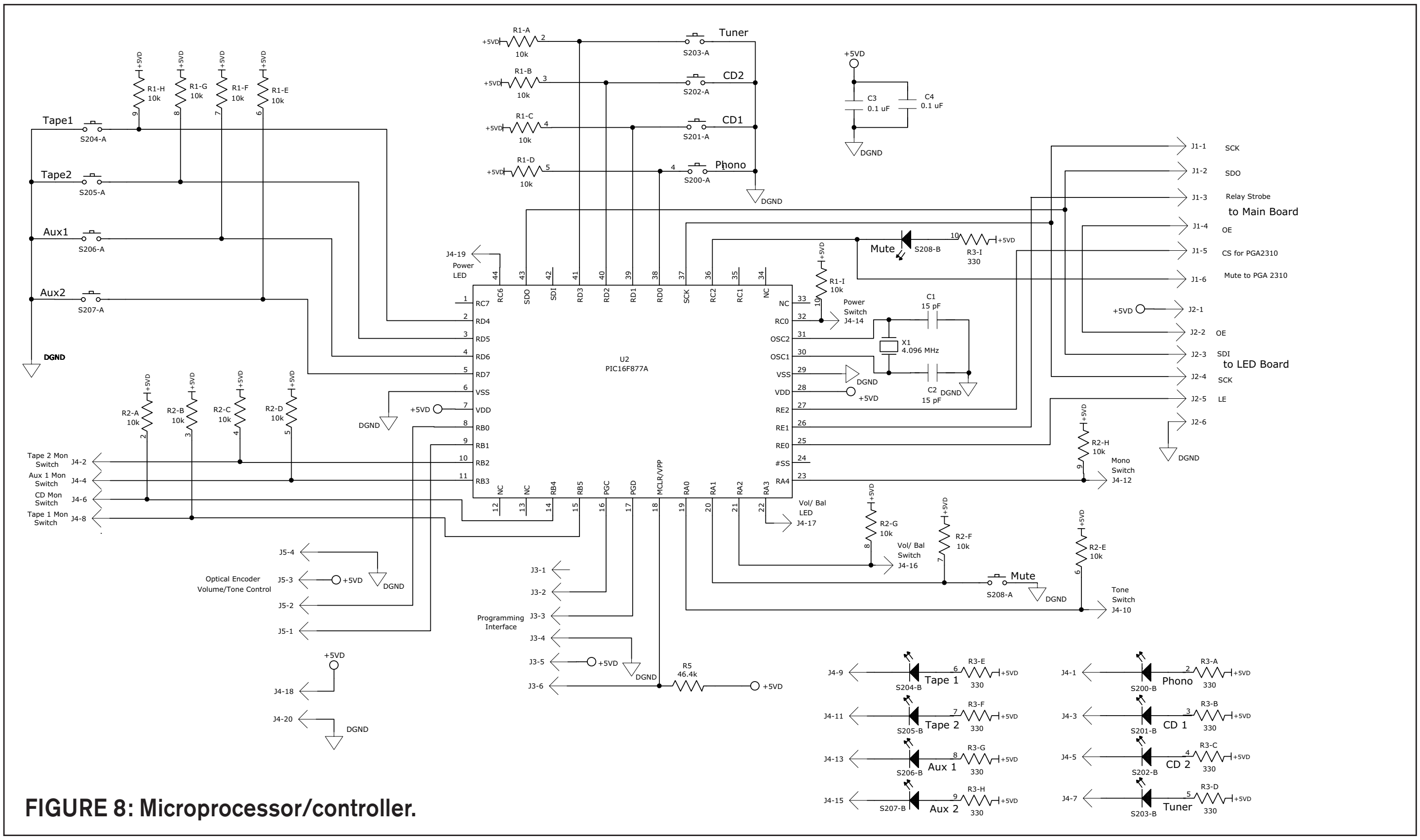


FIGURE 8: Microprocessor/controller.

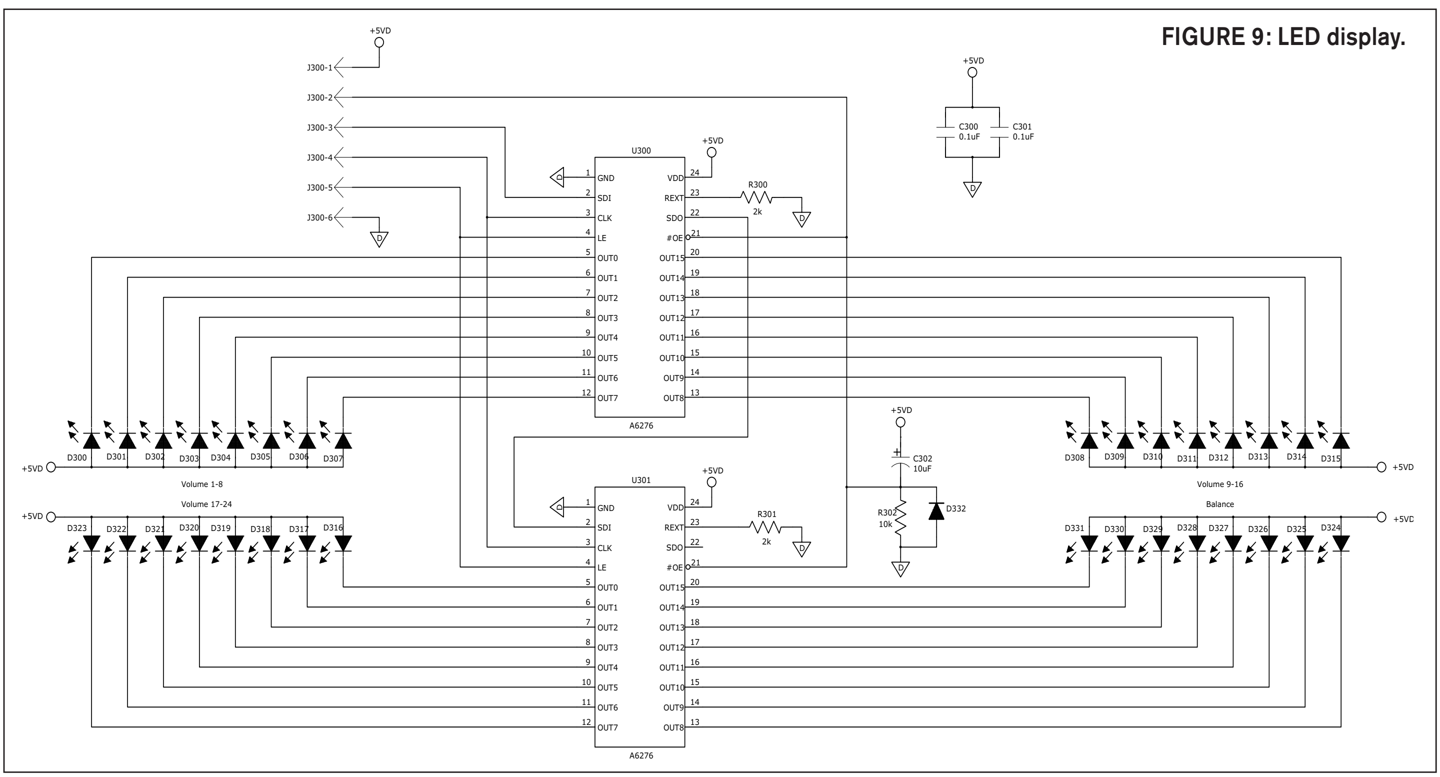


FIGURE 9: LED display.

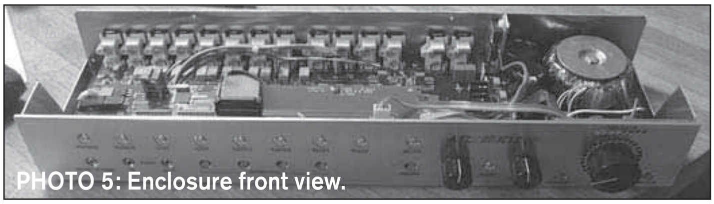


PHOTO 5: Enclosure front view.

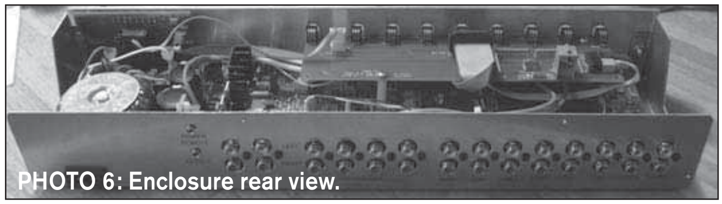


PHOTO 6: Enclosure rear view.

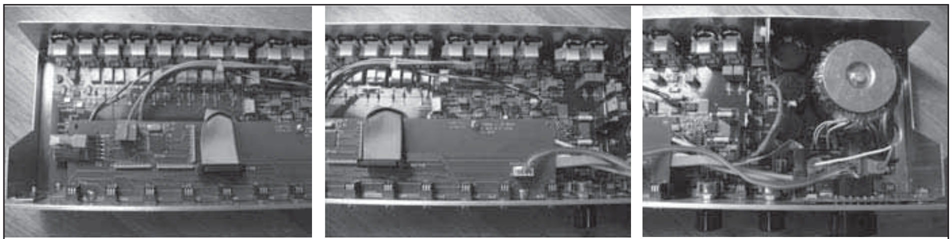


PHOTO 7: Assembled interior.

mize cabling. Boards are interconnected with ribbon cables.

FIRMWARE DESIGN AND FUNCTIONALITY

The core is a four-state machine, driven by the de-bouncing states of button pushes. This is, in turn, embedded in a main loop that responds to optical encoder state changes. Each time around the loop, the state machine checks to see whether a button has been pushed, and if so, it is timed for de-bouncing, and then checked for release, before the handling routine for that button is entered. Then, the power button and optical encoder state are checked, and the unit's operating condition is updated accordingly.

Optical encoder state changes result in increases or decreases of volume, or left/right balance adjustments if the control is in the "balance" mode. For more details including flowcharts for button functions, optical encoder reading, volume/balance adjustment, and volume and balance LED setting calculation and driving, check the website referenced in the parts list.

Some particulars of the firmware implementation that manifest themselves operationally are as follows:

- Input select, monitor, and mono/stereo switch states are retained in non-volatile memory, and are reinstated after a power down/up cycle.
- Balance is returned to center, volume is set to zero, tone controls are bypassed, and mute is turned off after a power cycle.
- The very first time a unit is powered up, all inputs are de-selected.
- Monitor buttons toggle. When one is pressed repetitively, it toggles on and off. If one is on, and another is pressed, the new monitor is selected, and the previous one cancelled.
- The volume control chip inherently is adjustable over a gain range of +31.5dB to –95.5dB in 255 0.5dB steps. This is far too much gain on the top end, because my gain plan calls for approximately +9dB overall. The optical encoder volume generates an 8-bit word from 0 to 255, which the processing firmware translates to –95.5dB at the low end and +8dB for full volume.

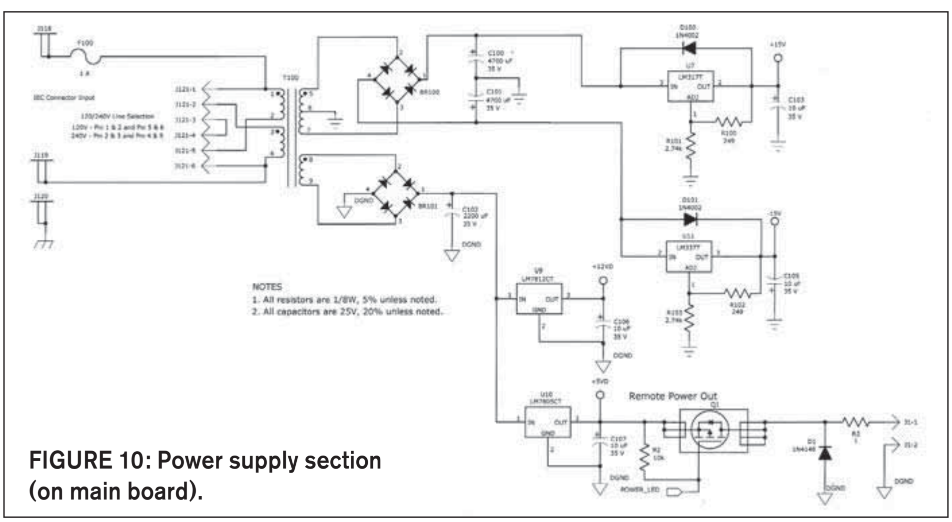


FIGURE 10: Power supply section (on main board).

ASSEMBLY GUIDELINES AND CONSIDERATIONS

Probably the most important aspect of construction is surface mount soldering technique, a topic I will not cover in detail here, except to say that a high-quality small-tipped soldering iron, fine (< = .032″) solder, copper braid solder wick, a good magnifier, a bright work light, and steady hands are essential. I recommend a very careful inspection and review process before powering anything up. **Table 2** is the parts list.

I leave parts choices and substitution up to you DIY readers, but I would not recommend substituting the following:

- The PGA2310 volume control chip
- The OPA2134 op amps, except if you know how to change compensation to maintain stability/compensation for an alternative
- The power FETs in the headphone amp
- The optical encoder, unless you chose one with the same encoding scheme and same number of transitions per rotation
- The poly/film capacitors, except with similar types—do not substitute ceramics or electrolytics for these

Areas where improvisation is encouraged include:

- The select push buttons. Their only requirement is a momentary contact and an associated LED. The ones shown are accommodated in the PCB layout, but others may be used and hand-wired.
- Input RCA jacks. The board is laid out for the particular Kobicon items, which are very convenient, but others may be hand-wired as your particular mechanical design accommodates.

The power transformer deserves some note. The digital power supplies require a separate winding, for which I found the addition of about 300 turns, 28ga, center tapped (150 + 150) to be about right. You can easily add these to the toroidal transformer specified. Alternatively, you can generate the digital supplies from the same AC winding that is used for the analog supplies, but this may compromise the hum/digital noise performance somewhat, although I have not tested this. You could also use a second transformer, or find/specify one that has the necessary windings to begin with.

I found installing all the surface-mount parts first the easiest approach to assembly. It allows the boards to lie flat, and also results in the least access interference for installing and soldering parts as you go along.

Before powering up the preamp, set both headphone amp bias adjustments to minimum bias. Then plug the preamp in and measure the voltage across R9A4R while adjusting R11A4R, until 60 to 80mV is reached, corresponding to a bias current of 30 to 40mA. Repeat for the left channel.

My enclosure is shown in **Photos 5** and **6**. It consists of two mating pieces of 0.050″ aluminum, one forming the bottom and back, the other the top, and a 1/8″ thick front panel. **Photo 7** shows the assembled interior.

PERFORMANCE

Performance data is shown in **Table 3**. The distortion figures, as you might suspect from the op amp datasheets, is respectable, although I put the greatest faith in the previously mentioned music comparison tests, and actual listening tests. The latter were performed with my HHB850 CD player, a pair of my designed FET power amps, and a pair of my designed speakers, employing KEF drivers. The results were exceptionally pleasing, but to claim any more here would be self-serving.

The ground plane main board appears to also have paid off, given the noise and crosstalk figures. *aX*

TABLE 3: PREAMP PERFORMANCE DATA

	Frequency	
Output level	1kHz	10kHz
150mV	.0042%	.012%
1V	.0007%	.0021%
2.5V	.0005%	.0016%

% THD vs. output voltage at 1kHz and 10kHz, with 50kΩ to 350Ω load

Noise	Better than –96dB ref. 2V
Crosstalk, any line level input pair or left to right channels	-95dB at 1kHz, -82dB at 10kHz

Noise and crosstalk performance

TABLE 2: PREAMP PARTS LIST

Part	Value/Description	Manufacturer	Source	Order #
U1	PGA2310 volume control	TI/Burr-Brown	Mouser	595-PGA2310PA
U2	PIC16F877A uProc	Microchip	DK	PIC16F877A-I/PT-ND
U3, U4	A6821SLW parallel driver	Alegra	DK	620-1096-ND
U7	LM317T	National	DK	LM317TFS-ND
U9	7812CT	National	DK	LM340T-12-ND
U10	7805CT	National	DK	LM340T-5.0-ND
U11	LM337T	National	DK	LM337TNS-ND
U300, U301	A6726ELW LED driver	Alegra	DK	620-1151-1-ND
U1A1L, U1A1R, U1A2, U1A3, U1A4, U1A5R, U1A5L	OPA2134	TI/Burr-Brown	DK	OPA2134UA-ND
F100	1A fuse	Littlefuse	DK	F2452-ND
Fuse holder (2)		Littlefuse	DK	F044-ND
K100-K114	AGQ20012	Panasonic relay	DK	255-1358-5-ND
D100, D101	1N4002, rectifier diode	Fairchild	DK	1N4002FSCT-ND
D102-D117	1N4148, protect diode	Micro Commercial	DK	1N4148-TPMSCT-ND
D300-D323	LTL-4261N, volume LED, red	Lite_On	DK	160-1035-ND
D324-D327	LTL-4261N, balance LED, red	Lite_On	DK	160-1035-ND
D328-D331	LTL-4231N, balance LED, green	Lite_On	DK	160-1142-ND
D332	1N4148, protect diode	Micro Commercial	DK	1N4148-TPMSCT-ND
S1-A-S8-A, S200-A-S208-A	K5V1BU43T, select push button	C&K	DK	401-1854-ND
S1-B	Button LED, blue, P/O S1			
S2-B	button LED, blue, P/O S2			
S3-B	button LED, blue, P/O S3			
S4-B	button LED, blue, P/O S4			
S5-B	button LED, green, P/O S5			
S6-B	button LED, blue, P/O S6			
S7-B	button LED, red, P/O S7			
S8-B	button LED, green, P/O S8			
S200-B	button LED, blue, P/O S200			
S201-B	button LED, blue, P/O S201			
S202-B	button LED, blue, P/O S202			
S203-B	button LED, blue, P/O S203			
S204-B	button LED, blue, P/O S204			
S205-B	button LED, blue, P/O S205			
S206-B	button LED, blue, P/O S206			
S207-B	button LED, blue, P/O S207			
S208-B	button LED, white or blue, P/O S213			
X1	ECS-41-20-4, 4.096MHz xtal	ECS	DK	X156-ND
J1	6 pin on CPU to main board	Tyco	DK	A34976-40-N
J2	6 pin on CPU to LED board	Tyco	DK	A34976-40-N
J3	RJ-45 programming on CUP board	Hirose	DK	H11250-ND
J4	20 pin on CUP to main board	Tyco	DK	A34976-40-N
J5	4-pin locking optical encoder connection			
J100-J106, J107-J110, J112, J113	1020-09-0600A, dual RCA	Kobiconn	Mouser	161-4221-E
J106A, J111A, J114	SJ1-3513, 1/8″ audio jack	CUI	DK	CP1-3513N-ND
J115	6-pin on main board from CPU	Tyco	DK	A34976-40-N
J116	20 pin on main board from CPU	Tyco	DK	A34976-40-N
J117	2-pin +5V remote enable power out	Tyco	DK	A34976-40-N
J118-120	Faston ¼″ terminals	Keystone	DK	1287K-ND
J121	6-pin power selector	Molex	DK	WM6436-ND
J300	6-pin on LED board from CPU	Tyco	DK	A34976-40-N
J1-1, 2a, J1-1, 2b	SJ1-3513, 1/8″ audio jack +5 remote	CUI	DK	CP1-3513N-ND
	IEC power receptacle/filter	Tyco	Mouser	592-6EEAP
	20 lead cable CPU to main board	Tyco	DK	A34976-40-N
	6 lead cable CPU to LED board	Tyco	DK	A34976-40-N
	6 lead cable CPU to main board	Tyco	DK	A34976-40-N
	4 lead cable CPU to optical encoder	Molex	DK	WM6436-ND
P1	600en-128-cbl, Vol/Bal opt. encoder	Honeywell	DK	600CS-ND
	knob, volume/balance	Tyco	DK	450-1696-ND
	knob, tone (2)	Tyco	DK	450-1701-ND
T100	power transformer	Avel-Lindberg	A/L	Y236003
BR100, BR101	KBP201G, bridge rectifier	Diodes Inc.	DK	KBP201GDI-ND
R1(a-h), R2(a-h)	10K, resistor SIP	Bourns	DK	4610X-1-103LF-ND
R3(a-h)	330 resistor SIP	Bourns	DK	4610X-1-330-ND
R5	46.4k, 1/8W film resistor	Rohm	DK	RHM46.4KCCT-ND
R100, R102	249, 1/8W film resistor	Rohm	DK	RHM249CCT-ND
R101, R103	2.74k, 1/8W film resistor	Rohm	DK	RHM2.74KCCT-ND
R104, R105	47.5, 1/8W film resistor	Rohm	DK	RHM47.5CCT-ND
R106, R1A5L, R1A5R, R2A5L, R2A5R, A3A5L, R3A5R, R5A5L, R5A5R, R6A5L, R6A5R	10k, 1/8W film resistor	Rohm	DK	RHM10.0KCCT-ND
R107	1.0, 2W, ERX-2SJ1R0	Panasonic	DK	P1.0W-2BK-ND
R108	330, resistor SIP	Bourns	DK	4610X-1-330-ND
R300, R301	2k, 1/8W film resistor	Rohm	DK	RHM2.00KCCT-ND
R302	75k, 1/8W film resistor	Rohm	DK	RHM75.0KCCT-ND
R1A1L, R1A1R, R2A1L, R2A1R, R1A2L, R1A2R, R1A3L, R1A3R	100k, 1/8W film resistor	Rohm	DK	RHM100KCCT-ND
R3A1L, R3A1R	681, 1/8W film resistor	Rohm	DK	RHM681CCT-ND
R4A1L, R4A1R	75, 1/8W film resistor	Rohm	DK	RHM75.0CCT-ND
R5A1L, R5A1R	750, 1/8W film resistor	Rohm	DK	RHM750CCT-ND
R6A1KL R6A1R	1M 1.8W film resistor	Rohm	DK	RHM1.00MCCT-ND
R7A1L, R7A1R, R3A2L, R3A2R, R4A2L, R4A2R, R3A3l, R3A3L, R3A3R, R4A3L, R4A3R, R4A4L, R4A4R, R7A4L, R7A4RR7A5L, R7A5R	3.32k, 1/8W film resistor	Rohm	DK	RHM3.32KCCT-ND
R8A1L, R8A1R	31.6k, 1/8W film resistor	Rohm	DK	RHM31.6KCCT-ND
R9A1L, R9A1R	221, 1/8W film resistor	Rohm	DK	RHM221CCT-ND
R10A1L, R10A1R, R5A2L, R5A2R, R5A3L, R5A3R, R9A5L, R9A5R, R10A5L, R10A5R	47.5k, 1/8W film resistor	Rohm	DK	RHM47.5CCT-ND
R11A1L, R11A1R, R1A4L, R1A4R	46.4k, 1/8W film resistor Rohm DK	RHM46.4KCCT-ND		
R2A2L, R2A2R,R2A3L, R2A3R	33.2k, 1/8W film resistor	Rohm	DK	RHM3.2KCCT-ND
R6A2L, R6A2R, R6A3L, R6A3R	4.64k, 1/8W film resistor	Rohm	DK	RHM4.64KCCT-ND
R2A4L, R2A4R, R5A4L, R5A4R, R6A4L, R6A4R	1k, 1/8W film resistor	Rohm	DK	RHM1.00KCCT-ND
R3A4L, R3A4R	2.2k, 1/8W film resistor	Rohm	DK	RHM2.21KCCT-ND
R8A4L, R8A4R	200, 1/8W film resistor	Rohm	DK	RHM200CCT-ND
R9A4L, R9A4R, R10A4L, R10A4R	2.2 2W, ERX-2SJ2R2	Panasonic	DK	P2.2W-2BK-ND
R11A4L, R11A4R	10K, PVG3A103C01R00	Murata	DK	490-2644-1-ND
R4A5L, R8A5L	100k pot, RV122F-20-15F-B100k	Alpha	Mouser	313-1250F-100k
R4A5R, R8A5R	100k pot, P/O R8FL	Alpha	Mouser	313-1250F-100k
C1, C2	15pF, C0805C150J5GACTU	Kemet	DK	399-1111-1-ND
C3, C4, C108, C109, C111, C113, C115, C300, C301, C9A1L, C9A1R, C11A1L, C11A1R, C5A2L, C5A2R, C6A2L, C6A2R, C6A3L, C6A3R	0.1µF, ECJ-1VB1H104K	Panasonic	DK	PCC2452CT-ND
C100, C101	4700/35V, ECO-S1VA472CA	Panasonic	DK	P6600-ND
C102	2200/35V, ECO-S1VA222BA	Panasonic	DK	P7466-ND
C103-C107	10/35V, T491C106K035AT	Kemet tantalum	DK	399-3766-1-ND
C110, C112, C114, C302, C8A1L, C8A1R, C10A1L, C10A1R, C4A2L, C4A2R, C7A2L, C7A2R, C4A3L, C4A3R, C7A3L, C7A3R, C5A5L, C5A5R, C6A5L, C6A5R	10µF, 25V, T491C106K025	Kemet tantalum	DK	399-3734-1-ND
C116, C117, C7A1L, C7A1R	2.2µF, BQ054D0225K	AVX	DK	495-1127-ND
C1A1L, C1A1R, C2A2L, C2A2RC2A3L, C2A3R, C7A5L, C7A5R, C8A5L, C8A5R	100pF, C0805C101J5GACTU	Kemet	DK	399-1122-1-ND
C2A1L, C2A1R, C1A2L, C1A2R, C1A3L, C1A3R	1µF, BQ074D0105J	AVX	DK	495-1119-ND
C3A1L, C3A1R, C5A1L, C5A1R, C1A4L, C1A4R	33pF, C0805C330J5GACTU	Kemet	DK	399-1115-1-ND
C4A1L, C4A1R, C6A1L, C6A1R	0.1µF poly, B32529C104J	EPCOS	DK	495-1103-ND
C3A2L, C3A2R, C3A3L, C3A3R	560pF, C0805C561J5GACTU	Kemet	DK	399-1134-1-ND
C2A4L, C2A4R, C3A4L, C3A4R	22µF 25V, T491D2266K025AT	Kemet tantalum	DK	399-3776-1-ND
C1A5L, C1A5R, C2A5L, C2A5R	0.033 poly, B32529C333J	EPCOS	DK	495-1100-ND
C3A5L, C3A5R, C4A5L, C4A5R	3300pF poly, B32529C332J	EPCOS	DK	495-1094-ND
Q1A4L, Q1A4R	ZXMN6A09KTC, N-channel power FET	Zetex	DK	ZXMN6A09KTCCT-ND
Q2A4L, Q2A4R	ZXMP6A18KTC, P-channel power FET	Zetex	DK	ZXMP6A18KTCCT-ND
Q100	IRF7416 or IRF7205	International Rectifier	DK	IRF7416TRPBFCT-ND

The following are available from A and T Labs at www.a-and-t-labs.com/K12_Preamp/index.htm.

K12PCB1	main board, four layer multilayer with ground and power planes	$69 each
K12PCB2	LED display board	$11 each
K12PCB3	microprocessor/controller board	$15 each
	Programmed PIC16F877A microprocessor	$15 each

Sources
Mouser—www.mouser.com
Digi-Key—www.DigiKey.com
Avel Lindberg—www.avellindberg.com
See also www.audioxpress.com/magsdirx/ax/addenda/index.htm for PC board layout and more.

By Ramkumar Ramaswamy

A Continuous-Time Active Filter

This crossover filter offers flexibility and control from the front panel.

PHOTO 1: AF-108.

Active (crossover) filters are not a new idea, having been around for decades. However, if you are on the lookout for an all-analog filter that offers the ability to continuously vary the crossover frequency via a simple front panel potentiometer, the choices are limited. Furthermore, if you also want the flexibility to play around with different transfer functions—again, by simply flipping a front panel rotary switch—your choices narrow down still further. These twin requirements led me to design the AF-108 continuous-time active filter (**Photo 1**).

Each filter PCB implements a 4th-order filter. To use this as a crossover for testing, say, a three-way speaker system, you would require three 4th-order filter boards. One board would realize the low-pass section, one the high-pass, and the remaining pair would realize the lower and upper ends of the midrange section.

STATE-VARIABLE FILTER

The circuit consists of several modules. At the core of it is a pair of standard state-variable 2nd-order filter sections that are cascaded to provide a 4th-order filter. You can find the 2nd-order state-variable filter (**Fig. 1**), a building block using standard op amps, in standard filter design books. I chose this because it is well documented and would provide me the greatest design flexibility. The realization of this for the first section of the AF-108 appears in **Fig. 2**; the second section is very similar and is not shown for brevity. Each section simultaneously provides a low-pass, a high-pass, and a bandpass output; I use only the low-pass and high-pass outputs. To get a 4th-order low-pass filter, the low-pass output of the first section feeds into the input of the second section, and the low-pass output of the second section is used. To get a 4th-order high-pass filter, the high-pass output of the first section feeds into the input of the second section, and the high-pass output of the second section is used.

The "characteristic" frequency of each state-variable section (which is *not* the same as the -3dB cutoff frequency commonly used in audio) depends on the values of R4, R5, C1, and C2, and the shape of the filter response (the transfer function) is governed by the resistors RA and RB that control the so-called damping factor. In our design, R1 = R2 = R3 = RB, R4 = R5, and C1 = C2.

THE ROLE OF THE VCA

To change the characteristic frequency of a section, therefore, you need to vary R and C. In the AF-108, this is accom-

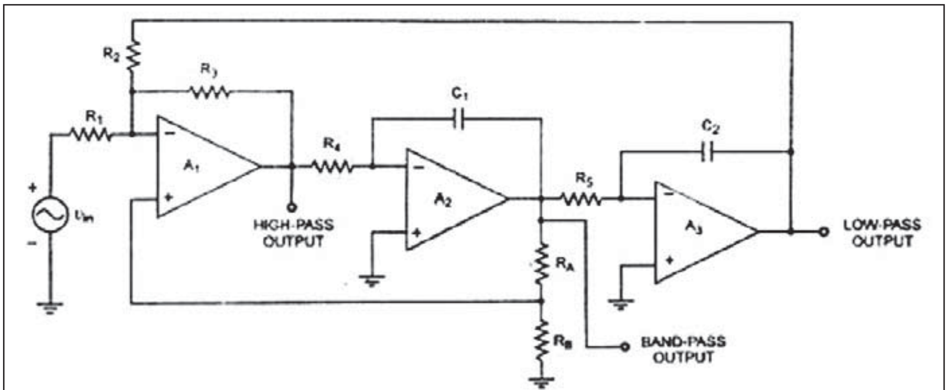


FIGURE 1: Standard three-op-amp state-variable filter.

plished as follows:

- Range switching is done in four bands, with C ranging in value from 470pF to 470nF
- Within each range, the frequency is varied continuously using a voltage controlled amplifier (VCA, the SSM2164 from Analog Devices) placed immediately after R4 and R5 in **Fig. 1**, which acts as an R-multiplier and changes the effective resistance "seen" at the inputs of A2 and A3, respectively. This accomplishes a frequency variation of 1:10 within a band. With the values shown, the characteristic frequency can be varied from 10Hz to 100kHz.

The master control voltage of the VCAs, which represents the overall characteristic frequency, is derived (**Fig. 3**) from the circuitry around current source CS1 (National LM285), buffered by one section of the MC33274. Note that CS1 (and other current sources in the system) is *not* temperature compensated because its tempco balances out the tempco of the SSM2164's control voltage!

CASCADING STATE-VARIABLE SECTIONS

When cascading two sections, though, the characteristic frequency of the overall filter is not necessarily equal to that of each section. Rather, the overall 4th-order filter's characteristic frequency is the geometric mean of the characteristic frequencies of the two sections. That is, for a given transfer function (say, Chebyshev), filter math states that to get a 4th-order characteristic frequency of f, the design needs to consider two specific frequencies f1 and f2, with $f = \sqrt{(f1f2)}$. This shifting of the characteristic frequencies above and below the desired characteristic frequency of the overall filter is accomplished using the current sources CS2 and CS3 (National LM285), whose current, when passed through the resistances RaX in **Fig. 3**, produce a positive and negative offset voltage around the center VCA voltage, which are then fed to the two sections independently.

SWITCHING BETWEEN TRANSFER FUNCTIONS

To change the transfer function, therefore, you need to do the following:

1. Change the damping resistors in

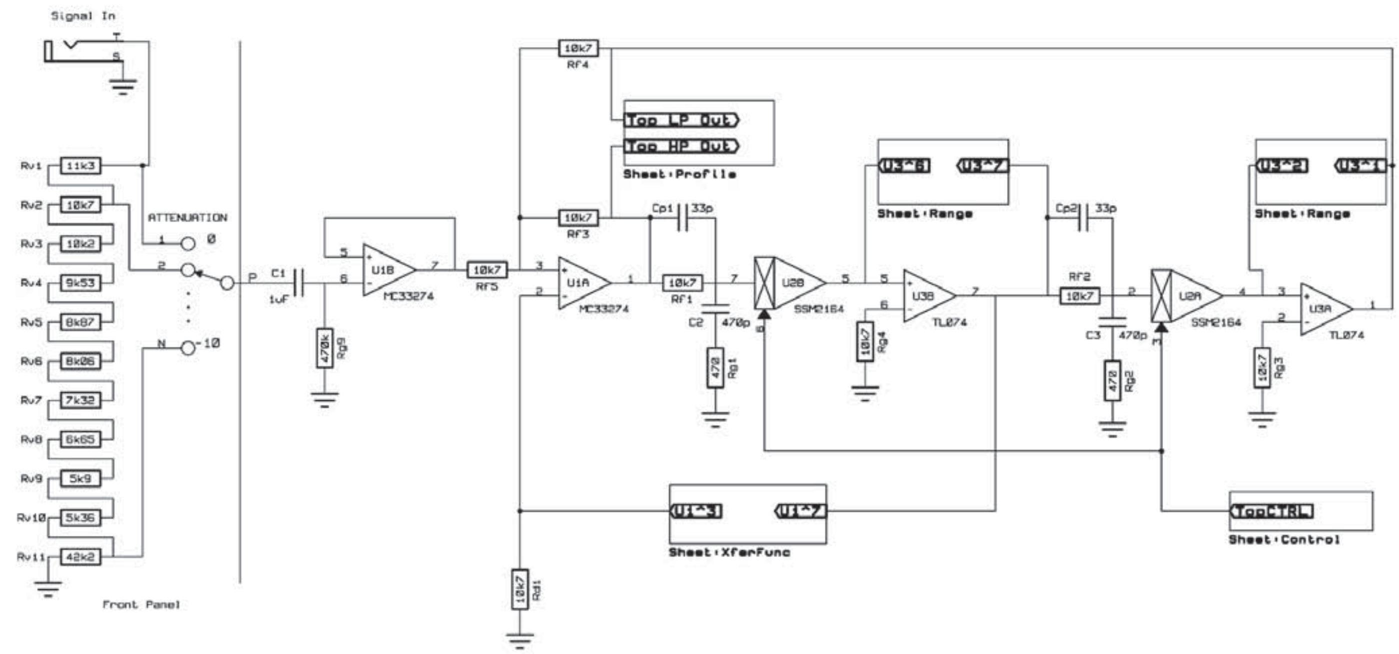


FIGURE 2: First state-variable section of the AF-108.

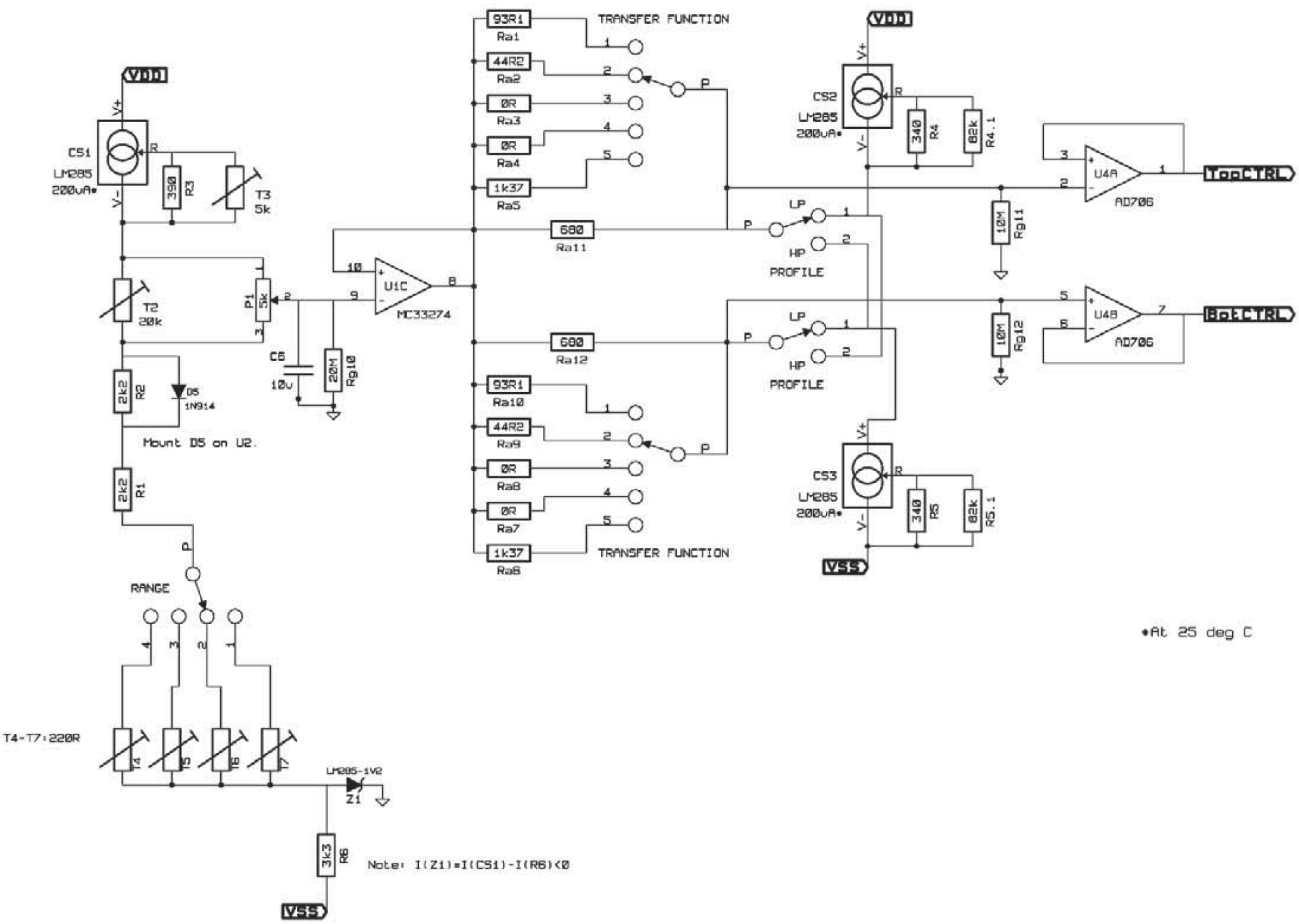


FIGURE 3: Frequency/VCA control.

each section.

2. Shift the characteristic frequency of each section above or below the overall characteristic frequency (how much to shift is dictated by the math of the filter's transfer function, which in turn determines the values of the resistors RaX).

LOW-PASS VERSUS HIGH-PASS PROFILES

Suppose you have cascaded two low-pass filter sections to yield a specific overall 4^{th}-order filter low-pass transfer function (say, Chebyshev). Designate the filter sections A[f1, d1] and B[f2, d2], where the symbols dj and fj refer to the respective values of the damping factor and the characteristic frequency. Then, curiously enough, filter math says that to get the corresponding *high-pass* transfer function, you will need to change the filter parameters in such a way that the new sections become A[f2, d1] and B[f1, d2]. This means that the offset voltages produced by CS2 and CS3 need to be "swapped," thus changing the characteristic frequencies of each section, and that is what is done using the Profile toggle switch in **Fig. 3**.

USE OF ANALOG SWITCHES

Given the amount of controlling and switching that happens in this system, you would expect lots of wires to run from PCB to the front panel. To completely isolate the circuit from the effects of noise and stray capacitance due to these wires, I decided to use the ADG609 and ADG436 from Analog Devices to achieve switching of the capacitor and resistor banks, and so keep all signals on the board (except, of course, the input and output). This allowed me to use plain unshielded ribbon cable for practically all of the board-to-panel wiring. Shielded cable is only used to wire the input and output jacks. (The switching circuits around the ADG436 and ADG609 are not shown here for brevity.)

The completed AFM-108 as shown in **Photo 1** was housed in a Schroff Multipac 2U enclosure with a Metalphoto® overlay.

FOR MORE INFORMATION

Boards, plans, custom-configured kits and design assistance for the AF-108 can be had from the author via www.audesine.com. *aX*

A 50W Pure Triode Power Amplifier

This efficient design, which delivers plenty o' output power, solved many of the author's triode-based power amp concerns.

Ten years ago I built a couple of 6C33C-B based OTL (output-transformer-less) power amplifiers using the asymmetrical push-pull output circuit. They sounded (sound) very good. However, I have a few issues with them.

First, they have limited output power, typically 25W per channel or less at 8Ω. Paralleling power triodes can double the output power. However, 6C33C-Bs are difficult to match, and I believe that a single output device per pole sounds better than the bigger brother version, let alone the extra heat generated to warm my home during the Australian summer. Also, the output power drops with load impedance—a 25-watter becomes a 12.5-watter when you use a 4Ω loudspeaker.

Second, the DC offset varies between ±100mV (this depends on the bias current, supply voltage variation, and so on).

Third, OTL designs are very inefficient, possibly the least efficient design in audio amplifiers.

These issues are not really disastrous, and I have been using this design for a few years without problems. Six or seven years ago, I acquired a pair of 1kΩ (plate-plate), 50W output transformers 9141s from Sowter (this exact model is no longer available, www.sowter.co.uk). I built and tested a 6C33C-B-based transformer-coupled push-pull amplifier using a circuit similar (but not identical) to the one described in reference 1. However, I did not think that it was comparable with the OTL design then.

I have been using two pairs of loudspeakers—the very inefficient Harbeth L3/5A with 84dB/W/m and the slightly better ProAc 2.5 equivalent at 87dB/W/m. The OTL works very well if I ensure that the output power limit is not exceeded. However, this is almost impossible for realistic sound level reproduction.

Consequently, I built a few triode-MOSFET hybrid power amplifiers and even a class-D amplifier. I must say that I still prefer a triode-based power amplifier. Therefore, last year I decided to retrieve this amplifier and came up with a new design. Mellow's recent article[2] reminds me of the benefits of OTL amps, and he has cleverly solved the DC bias drift problem mentioned above.

Anyway, not everyone can live with a 25W amp and I myself need a pure valve amplifier with reasonable power and drive. So I came up with the design described in this article. This project involves high voltages with a lot of heat and does not suit first-time DIYers.

BASIC CIRCUIT DESIGN

This design is a pure triode transformer-coupled push-pull amplifier. The major difference is that the driver stage (also works as a phase splitter) is now directly driving the output stage and there is only one coupling capacitor in the circuit. I believe this improves the sound quality by one level (6C33C-Bs and other high current triodes are reportedly hard to drive). Incidentally, Mellow[2] uses the same direct drive approach, perhaps with a different reason.

My initial design was based on the 6C33C-Bs, and I soon discovered that I could not get the power (or the bias condition) I wanted from the output transformer. In order to achieve 50W–60W at 8Ω load, the triodes need a plate voltage of well over 250V for a 1kΩ transformer. Unfortunately, the power rating of a 6C33C-B drops from 60W to 30W with a plate voltage of 250+V. I can run the triodes at a very low bias current to keep the DC power dissipation low; however, the amp must run close to class-B and the linearity of a triode at low current deteriorates.

I then switched to the 6336-As, which have a similar rating but not the 250V limitation. **Figures 1A** and **1B** show (one channel of) my final design, which is based on the 6336-As. The input stage (**Fig. 1A**) is a 12AT7 common-cathode amp biased by a current source.

The bias voltage (VPK) is fixed by the diode voltage plus the voltage across R3. The bias condition is very stable and VB can range from 150V to 220V. I use 12AT7 instead of the popular 12AX7 because I can source the former at a much cheaper price. I believe a 12AX7 will do the job just fine, but the bias current should be reduced to around 1mA by increasing RX (to about 1.1k). **Figure 2A** shows the current source, which is designed to produce 3.3mA.

It is not necessary to fix the current exactly at this value. The major objective is to achieve a stable bias and perhaps you can experiment to find the "best" bias yourself. If you do not like semiconductors in the circuit, then you can revert to a more conventional common-cathode design with suitable plate and cathode resistors.

Before I describe the second stage, first consider the theoretical design of the output stage. **Figure 1B** shows a typical push-pull topology with two triodes of each 6336-A connected in parallel. Two 6336-As (or four triodes) are needed to form the push-pull pair. There are two major factors that determine the output power of the stage.

They are the transformer's primary reflected impedance (at the designed load) and the plate-cathode voltage (VPK) of the triode. Current delivery is not a major concern in this case. You can use 6336-As in an OTL design. I have a 1kΩ transformer, and I can show that each triode is seeing a 1kΩ load when the secondary is terminated by an 8Ω resistive load. I also have a 220V 300VA power transformer handy, and so the DC supply (VB1) is around 308V.

In order for each of the two triodes to share (nearly) the same amount of current, you need cathode resistors. The major problem is that I need a big cathode resistor which dissipates a lot of heat and requires a higher supply voltage. So I started the design with a 100Ω cathode resistor (will change later) on each leg.

Figure 3 shows the output characteristics (from Raytheon) of each output triode, which is close enough to assume VPK to be 300V. If I pick a bias current of 60mA such that the plate dissipation is 18W, which is well below the 30W limit, the bias voltage VGK is -100V and the power output is 60W into 8Ω. This is the theory, although in practice I achieve different results as I will explain later.

I need VGK = -100V and therefore VG (=VGN=VGP) = -(100 – 100 ×60m) = -94V. I want the driver to be directly coupled to the grid of each output device, and hence the DC voltage of the driver at this connect point must be -94V. As in a common push-pull design, I need a phase splitter. The solution is the long-tailed pair.

The first stage is capacitor-coupled (this is the only coupling cap) to the second, which uses the two halves of a 5687 (**Fig. 1A**) to form the long-tailed

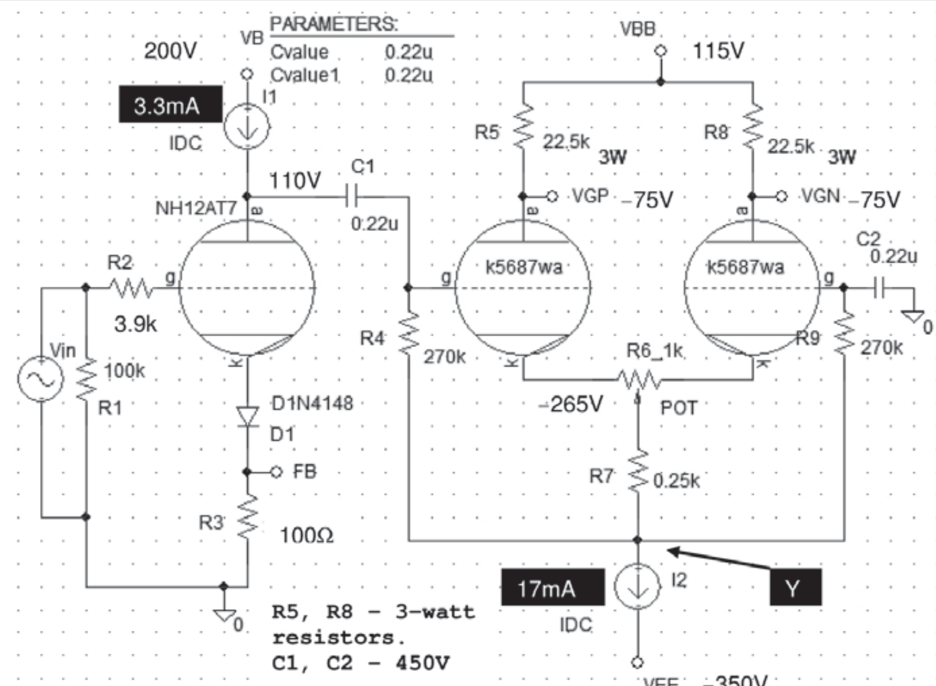


FIGURE 1A: The input and driver stages.

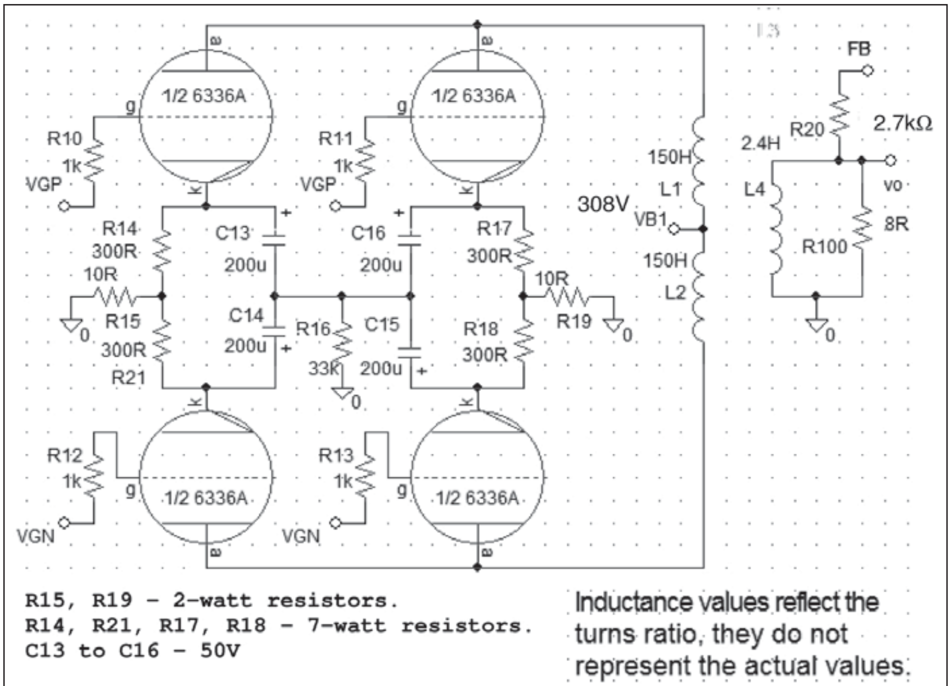


FIGURE 1B: The output stage.

pair. The basic topology is no different from any typical design except that the plate voltages must be negative because they are connected to the grids of the output devices. As a result, a very negative VEE (-350V) is needed. This stage is biased by the current source of **Fig. 2B**.

The plate voltages depend on the output stage, and, therefore, unlike the first stage, two essential adjustments are needed. First, the current source of **Fig. 2B** controls the bias current, which, in turn, controls the plate voltages. Second, R6 (the 1k pot of **Fig. 1A**) adjusts the balance between the two plate voltages.

Figure 1A shows -75V each, but in practice the two voltages are different depending on the output devices and other conditions. I use a 500R pot (RY of **Fig. 2B**) for the control, from which the minimum current is around 7.5mA. I can add a series resistor of 100R, say, to limit the maximum current to around 38mA when RY is zero. As I will show later, it is better to start with a higher bias current.

Assuming the two halves of the 5687 are sharing an equal amount of current, then each plate voltage is (VBB – Ip × R5). A good approximation is that VBB is relatively constant at 115V, so the plate voltage can range from -42.5V to -110V if the plate current varies from 7mA to 10mA. This shows that the circuit is capable of generating a wide range of plate voltages and shows why a good-quality multi-turn pot is suggested. The usable range is -60V to -90V; otherwise, the stage distortion increases. In principle, you could use a suitable resistor with a pot to replace the current source; however, in this case I believe the performance and control would be inferior to the current source control.

The basic circuit works in open-loop; however, it is not designed to work under this condition because the output impedance is high (2-3Ω) and so is the distortion. Therefore, the circuit is closed with the feedback pair R3 and R20. The overall gain is 26dB with around 12dB of negative feedback when R20 is 2.7k. You may change it from 1.5k to 3.9k, with the corresponding overall gain being 22.5dB and 28.5dB, respectively.

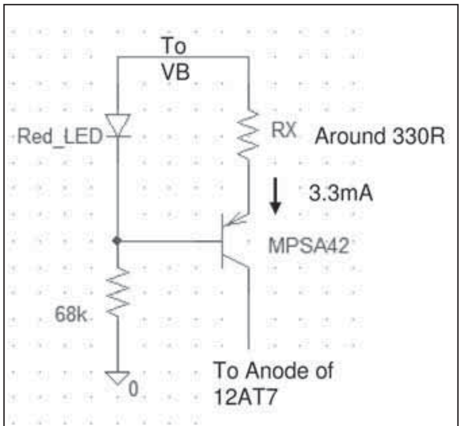


FIGURE 2A: Current source for the input stage.

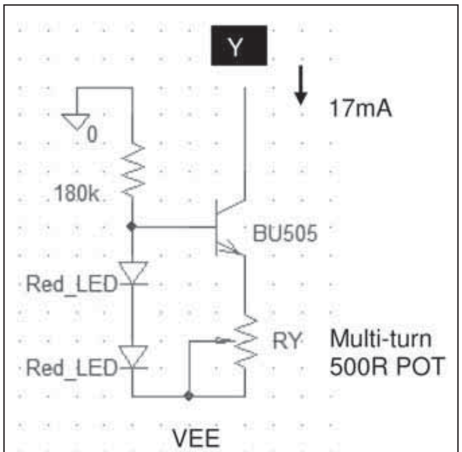


FIGURE 2B: Current source for the driver stage.

PRACTICAL IMPLEMENTATION

The circuit does not need a special power supply, but needs various voltage levels. It may be difficult to source a single transformer to do the job. I use a separate 12V 250VA transformer with floating secondary for the heater filaments (ideally, the 5687 heaters should be fed by a separate 12V winding with one terminal referenced to around -260V—similar to Fig. 3 of reference 2).

I do not need to use DC heating. I have separate transformers for the high voltages and the negative supply. Each power supply circuit is typical. If you need help, consult references 1 and 2. Voltage levels shown in **Figs. 1A** and **1B** are not absolute, and a variation of a few percent should not be a problem.

I don't have any special preference for resistor or capacitor types, provided that they meet the power and voltage requirements. Larger power resistors are indicated in appropriate figures. The transistor in **Fig. 2B** must be heatsinked (a small heatsink will do)—I use BU505. You can use an equivalent power transistor with at least a 500V rating. Filter capacitors should be as large as practically possible, and a C-L-C filter circuit is preferred[1].

It is important that the front stages be adjusted before turning on the output stage. I use separate transformers, and I make adjustments manually. The first stage needs no adjustment. For the second stage, I start to adjust RY (with the wiper initially at the middle) such that VGN and VGP are -100V or more negative to ensure that the output stage currents are not excessive. It means that, for the second stage, I start the adjustment with a higher bias current as stated before. I use POT R6 to balance VGN and VGP, but no precision adjustment is needed at this stage. After a few minutes you can switch on the output stage.

When I first did the testing a year back, I started with 100Ω cathode resistors for the 6336-As. All measurements were fine and fairly close to my expectations. However, the bias currents tended to drift a bit over time.

I increased the value of the cathode resistors and eventually stopped with 300Ω to each leg of the output triodes. The higher value increased the output resistance of the stage, and so I added bypass capacitors. Finally, I added current-measuring resistors to sense the total current of each 6336-A. The final design is shown in **Fig. 1B**.

R15 and R19 measure the currents of each 6336-A, while R14, R21, R17, R18 measure individual currents through each triode. The result is that the voltage VPK drops, and so does the output power. The supply transformer winding and the choke resistances worsen the problem, so that the output power is now limited to 50W. I believe this is a good combination of cathode and negative bias, and 50W works for me.

If I keep the bias current of each triode at 60mA, then the voltage across R14 (and R19) should be (60m × 10 ×2 =) 1.2V. VPK is around 290V, and the corresponding VGK and VG are -96V and -76V, respectively. Because I start the adjustment with VG = -100V, all 6336-As are practically off. I adjusted RY to reduce the driver currents and at the same time monitored the voltage across R14 (a typical DMM will do).

When this voltage was around 0.5V, I stopped to check the voltage across R19 and adjusted R6 to keep the two voltages equal. I repeated the process until both voltages were 1.2V. It is more convenient if you have a second DMM to monitor the voltage across R19. Eventually, the four 5687 plate voltages ranged from –66V to -76V for my amplifier.

As with most valve power amplifiers, you should check the bias regularly. I use Tung-Sol (and Chatham) 6336-As and am quite happy with their performance. First, they have good balance between the two halves, and, second, they need very little adjustment over time. I can use the LEDs of **Fig. 2B** as indicators that the driver is working. You can also add an LED between each plate of the 5687 and the corresponding plate resistor and use the brightness as a further indication. If you prefer more class-A, then you can always increase the bias current. Just keep in mind the datasheet maximum plate dissipation is 30W for each triode.

This amplifier runs hot, and good ventilation is essential. I estimate the power dissipation is in excess of 250W when idle. Fortunately, I have a spare external cooling fan that I use as necessary.

Even after making all the necessary adjustments, you must follow this turn-on sequence:

- Heater supply
- High voltages (including the –ve supply) to the input and driver stages
- Supply to the output stages.

I needed an additional AC adjustment before the amplifier could perform. With feedback, the unit is likely to give an overshoot on a square-wave response and a peak at high frequencies in the frequency response curve.

I have a 300pF capacitor (not shown in **Fig. 1B**) connected across R20 to minimize this effect. The capacitor value depends on the output transformer, and practical measurement is usually needed unless you have the details of the output transformer. You can use this capacitor to adjust the square-wave response and bandwidth. You will need an audio signal generator and a cathode-ray oscilloscope to check AC measurements.

In order to complete the picture, I include some typical (AC) measurements here. In all cases that follow, the load is 8Ω and R20 is 2.7k with a 300pF parallel capacitor:

- Voltage gain: 26dB, non-inverting
- -1dB bandwidth: better than 5Hz to 80kHz, with a 1dB peak at 50kHz
- Slew-rate: 1MV/s
- Output impedance: 0.5Ω
- Maximum unclipped power: 50W

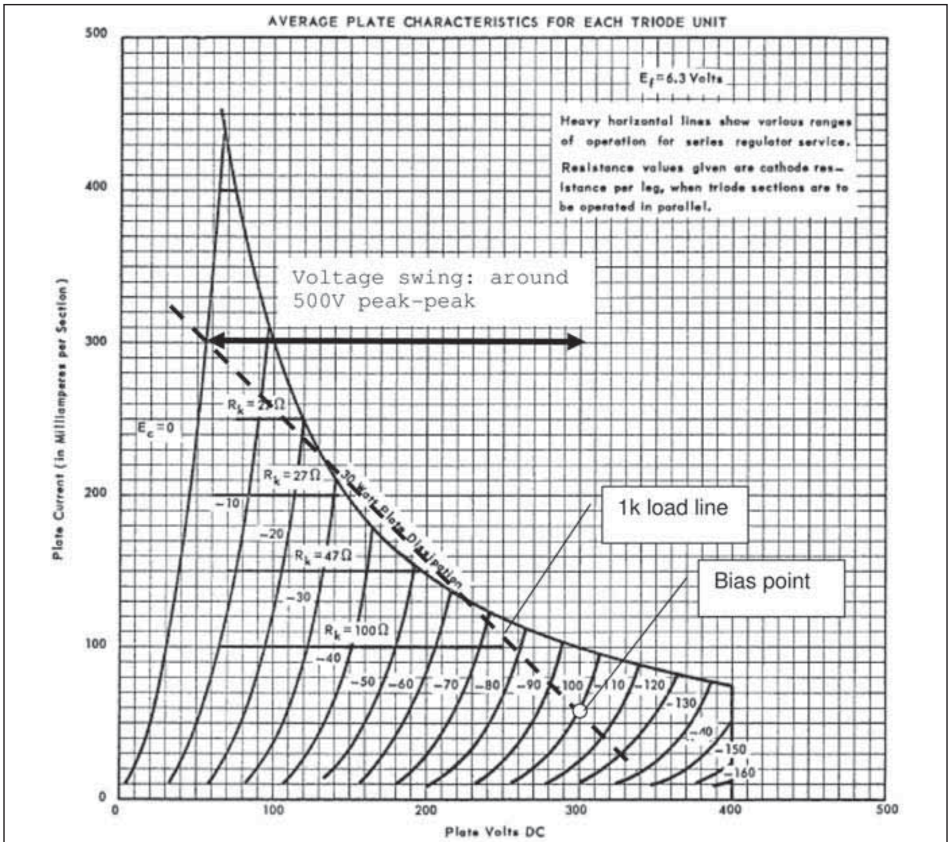


FIGURE 3: The output characteristics (from Raytheon) and the load line.

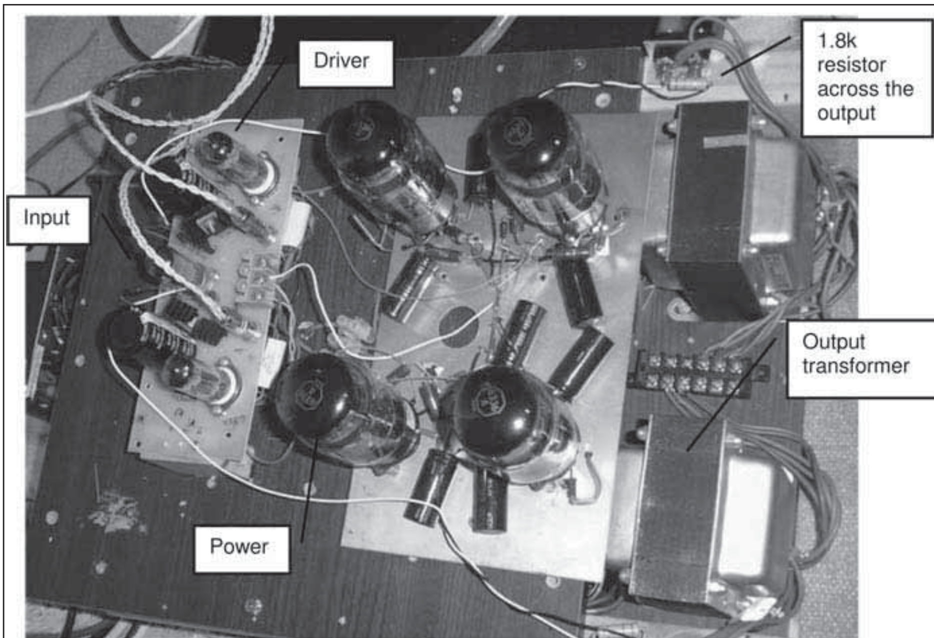


PHOTO 1: The prototype. The 1.8k resistor is not shown in the schematics. Warning: this is a prototype only and should not be the final form of any version which the reader plans to build.

• Total harmonic distortion (THD) including noise: <3% at 40W across the audio spectrum.

In this design I tend to place output power before distortion. However, you can experiment with improving distortion by increasing the bias current or the feedback or both. Each 6336-A is dissipating around 33W (+ heater power), and it can take a 50% increase in bias current.

Under this condition fan cooling is mandatory. I understand that many consider the use of feedback is sinful; however, I think feedback is useful provided that the open-loop response is reasonably good and that no excessive feedback is applied (under 20dB). I am currently using 12dB of feedback. This amplifier has ample open-loop gain to accept an additional 6dB feedback. The sound is more open and fresh with less feedback. On the other hand, it exercises more control with higher feedback. My preference is to apply 9 to 12dB of feedback.

The prototype is shown in **Photo 1**. The supply circuits are under the main boards, while power transformers are external.

CONCLUSION

I have been using this amp for over a year now. Although I cannot say that it sounds better than an OTL, I have no desire to switch back to the OTL. The current design provides much more power and is surely more load tolerant. In this respect, it is even better than many tetrode/pentode-based amps.

The valve count is only seven for a two-channel amplifier and shows a good compromise between simplicity and quality. 12AT7s and 5687s are plentiful and cheap. 6336-As are also commonly available at a reasonable price, even though there are no current productions. The output transformers are likely to be the most expensive items.

I am currently using a pair of Mullard E182CCs as the drivers after trying various 5687s. The E182CCs seem to give a crisper and faster sound. I am sure some would suggest that 5687s are more romantic and musical. (Remember to rebias after a driver swap.)

I have used the 6C33C-Bs briefly before the 6336-As. I believe that the former tends to be more "modern" and the latter more "conventional." Anyway, 6C33C-Bs do not suit the current design. They have slightly better current handling capability and suit a high-bias class-A (or class-AB) design with a reduced plate-cathode voltage (<250V) and hence lower output power. In this case, I would probably go for a 600Ω output transformer from which you may get even more power.

REFERENCES

1. Kees Heuvelman and Wim de Haan, "6336-A-Based All Triode PP Amp," *audioXpress*, pp. 25–34, May 2005.

2. Tim Mellow, "A 25W OTL Tube Amplifier," *audioXpress*, pp. 12 – 17, February 2010. aX

A Tang Band 3″ System

In Part 2, the author builds a system with available TB drivers.

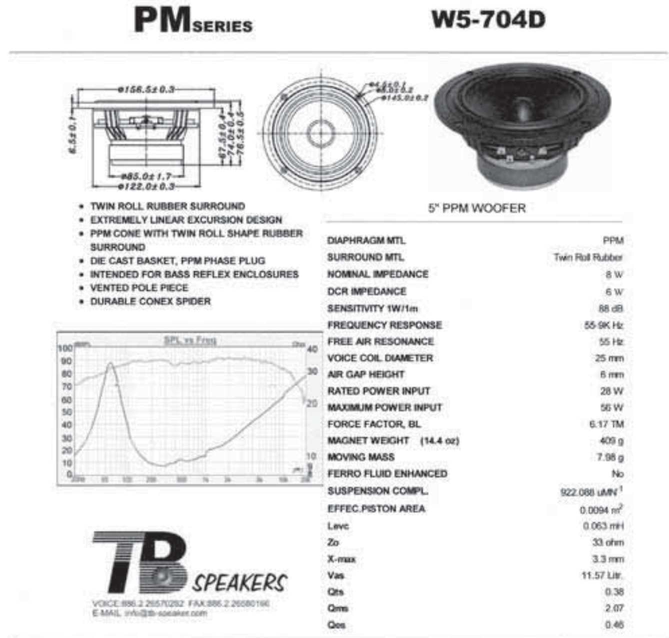
I have demonstrated that you can build a near-zero-phase system with one pair of TB drivers having a large frequency overlap ("Tang Band Full-Range System," May '10 *aX* p. 04). The question remains: Is this a general result? Can you combine any pair of TB drivers with this wide frequency overlap to produce a near-zero-phase system?

To investigate this I decided to buy pairs of current TB drivers and see whether I could design such a system. I decided to try the TB W5-704D woofer (assigned reference #213). This driver would give the small system reasonable power and X_{max} ratings. I noted TB now offered a 3″ coaxial driver, the W3-1723 (reference #214), which might allow for a smoother top-end. I ordered pairs of both drivers (www.tb-speaker.com).

The #213 woofers turned out to be about as expected. **Figure 11** shows the on-line TB data for this driver. Note that the boxes now contain a sticker saying these are 5¼″ woofers, indicating TB has adopted the standard way of stating the nominal size of drivers. **Figure 12** shows my measurement of the response match of my pair, and **Fig. 13** their off-axis performance.

The PPM cone material "goes away" much smoother at high frequency than does the metal cone of the #180 woofer, which should yield an easier CO design. **Photo 4** shows the front and rear views

PHOTO 4: Front and rear views of #213 5¼″ woofer.



PM SERIES W5-704D

- TWIN ROLL RUBBER SURROUND
- EXTREMELY LINEAR EXCURSION DESIGN
- PPM CONE WITH TWIN ROLL SHAPE RUBBER SURROUND
- DIE CAST BASKET, PPM PHASE PLUG
- INTENDED FOR BASS REFLEX ENCLOSURES
- VENTED POLE PIECE
- DURABLE CONEX SPIDER

5" PPM WOOFER

DIAPHRAGM MTL	PPM
SURROUND MTL	Twin Roll Rubber
NOMINAL IMPEDANCE	8 W
DCR IMPEDANCE	6 W
SENSITIVITY 1W/1m	88 dB
FREQUENCY RESPONSE	55-9K Hz
FREE AIR RESONANCE	55 Hz
VOICE COIL DIAMETER	25 mm
AIR GAP HEIGHT	6 mm
RATED POWER INPUT	28 W
MAXIMUM POWER INPUT	56 W
FORCE FACTOR, BL	6.17 TM
MAGNET WEIGHT (14.4 oz)	409 g
MOVING MASS	7.98 g
FERRO FLUID ENHANCED	No
SUSPENSION COMPL.	922.088 uMN^{-1}
EFFEC.PISTON AREA	0.0094 m^2
Levc	0.063 mH
Zo	33 ohm
X-max	3.3 mm
Vas	11.57 Litr.
Qts	0.38
Qms	2.07
Qes	0.46

TB SPEAKERS

FIGURE 11: Tang Band data for #213 (W5-704D) woofer.

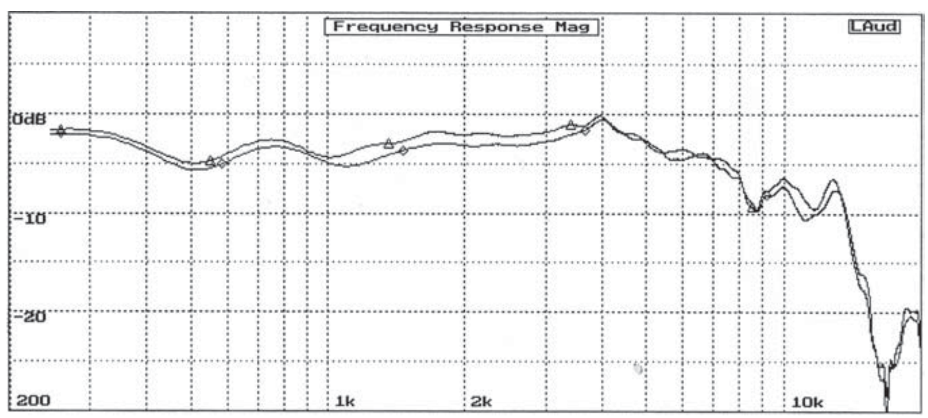


FIGURE 12: Measured response match for pair of #213 woofers.

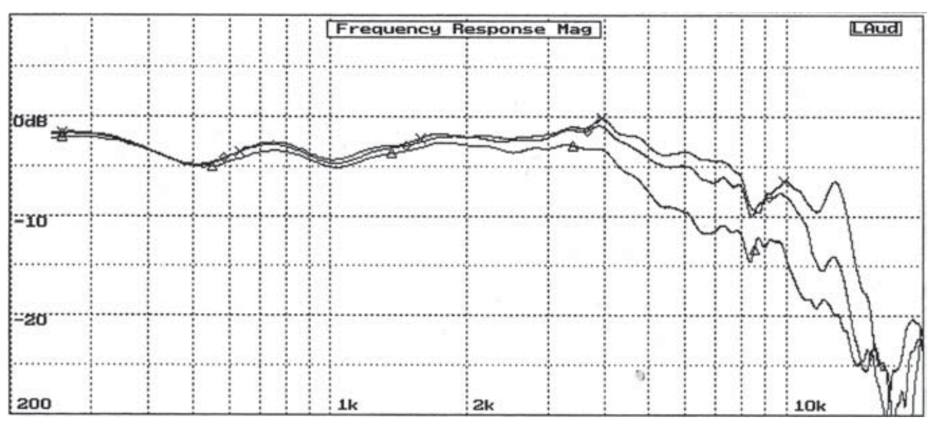


FIGURE 13: Measured on-axis and 10 and 20° off-axis responses for #213 woofers.

of this driver, which has a die-cast basket. Note the unusual dual half-roll surround. I have used a TB woofer with this feature in the past and was very happy with the results. Note also that what appears to be a fixed phase plug is actually a dust cap that moves with the cone.

TANG BAND 3″ COAXIAL DRIVER

The reference #214 coaxial driver turned out to have problems right from the start. The 2009 Parts Express catalog listed the W3-1723SA (part number #264-827) as coming with the crossover. However, opening the boxes revealed they were without CO or any information about what the CO should be.

Per TB, the W3-1723S comes with the CO and the W3-1723SA without the CO. My drivers came in boxes marked W3-1723SA (no CO), but had a factory-installed label saying "with crossover." So the confusion was definitely on TB's end and not with Parts Express. Parts Express contacted TB and forwarded **Fig. 14**, covering data on the #214 driver and the recommended CO schematic.

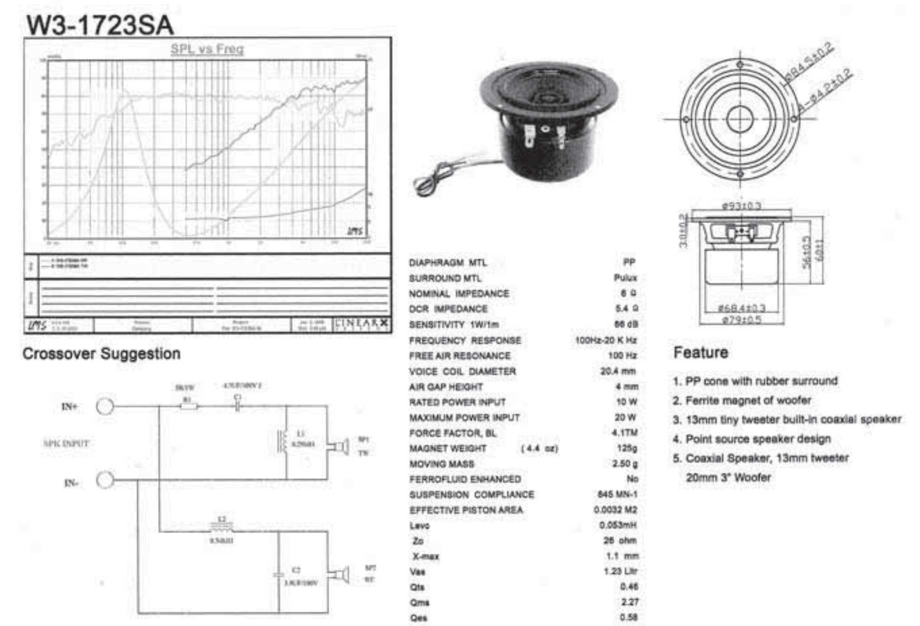


FIGURE 14: Tang Band data and crossover for #214 (W3-1723) coaxial driver.

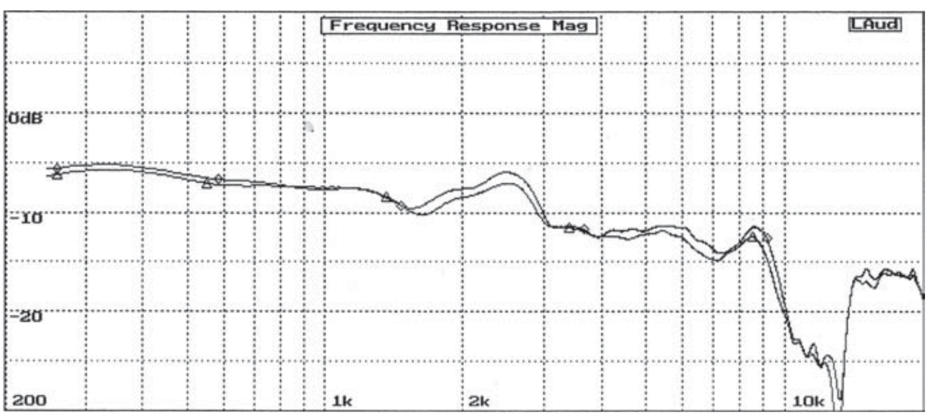


FIGURE 15: Measured response for midrange portion of two #214 drivers.

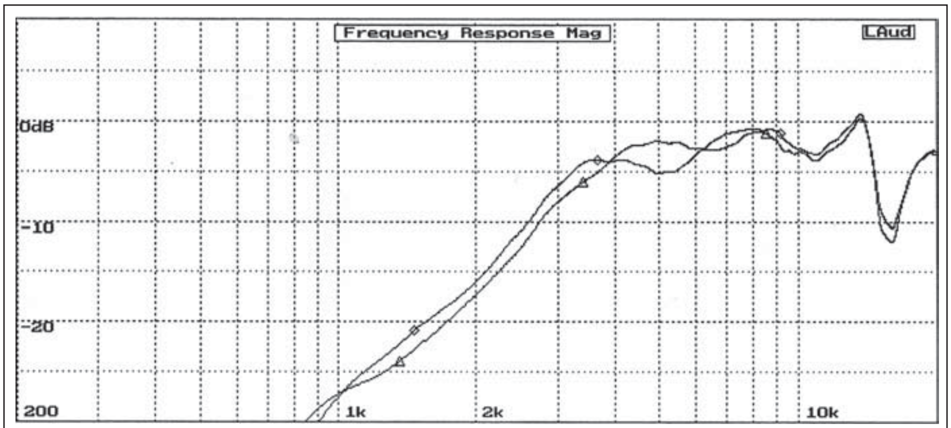


FIGURE 16: Measured response for tweeter portion of two #214 drivers.

Figure 15 shows measured midrange-portion responses, and **Fig. 16** the tweeter-portion responses for my pair of #214 drivers. It is clear that the tweeter portions do not match well, and there is very little range of overlapping-frequency response between the two portions. **Figures 17** and **18** show the off-axis responses for the midrange and tweeter portions, respectively.

Photo 5 shows front and rear views of the 3″ coaxial driver. Note this driver uses a sheet-metal basket formed into a channel at the outside diameter. The photo shows I have filled the opening in this channel with rope putty. I do this for three reasons. First, it forms the air seal when the driver is mounted. Second, I have found in the past that such channels can "ring" and modify the driver response. Finally, it helps to prevent the channel from distorting when you tighten the mounting screws.

I implemented the TB recommended CO (**Fig. 14**) and tested one of my #214 units. Note **Fig. 14** does not indicate whether the two portions are used in- or out-of-phase, so I tested both ways (**Fig. 19**). Clearly you want both portions in phase, but even that response is not very good with a depressed upper-midrange response. I decided to develop a better CO via modeling. There was no possibility of a true minimum-phase CO due to the lack of frequency-response overlap between the midrange and tweeter portions of the coaxial driver.

PHOTO 5: Front and rear views of the #214 3″ coaxial driver.

Figure 20, with #214 unit B, shows the modeled response with the revised CO of **Fig. 21**. **Figure 22** shows the measured response with the revised CO with both #214 units. Unit B is as modeling predicted, but unit A is much rougher. I modified the CO (**Fig. 23**) to produce a better response with unit A (**Fig. 24**). With both these COs both driver portions are connected with positive polarity.

The only difference between these two COs is the added 6.8mF capacitor in series with the tweeter section for unit A. If you are using the W3-1723 with the factory-recommended CO and believe it has a suppressed midrange, you might try my revised CO. Play with a capacitor in series with each tweeter portion until you get the two drivers to sound the same.

The result of this work was that there was no way to use the #214 coaxial driver as the top end for a zero-phase system. If you prefer to build a non-minimum-phase system with the #213 and #214 driver pair, **Fig. 25** shows the expected performance of this three-way system including correction for 3dB of diffraction spreading loss based on an enclosure

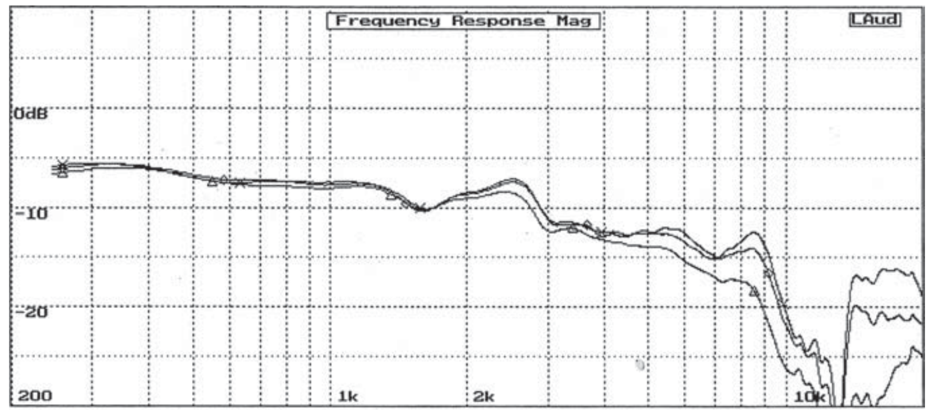


FIGURE 17: On- and off-axis response of midrange portion of #214 driver.

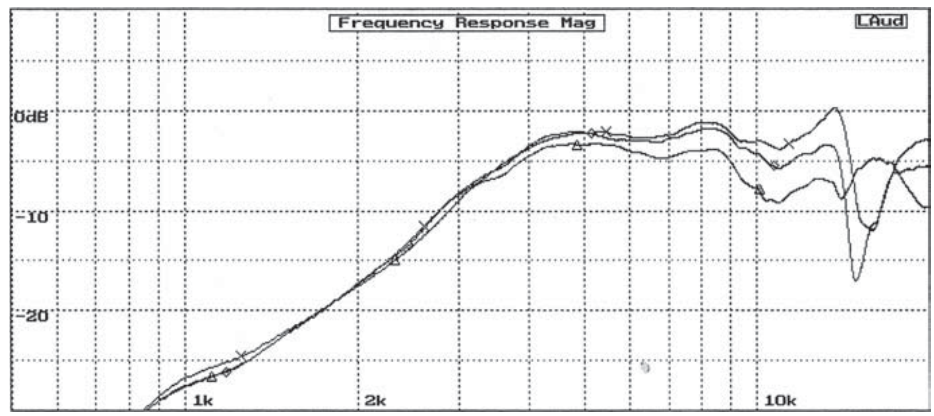


FIGURE 18: On- and off-axis response of tweeter portion of #214 driver.

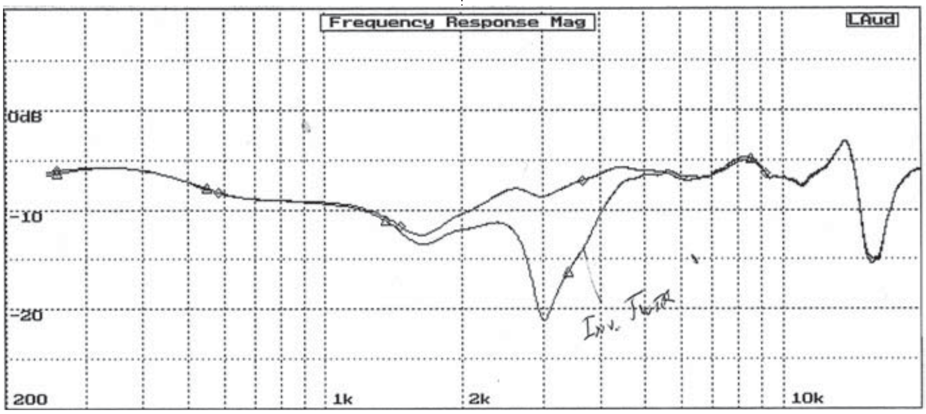


FIGURE 19: Performance of #214 driver with TB's recommended crossover.

PHOTO 6: Front and rear views of #215 3″ mid/tweeter.

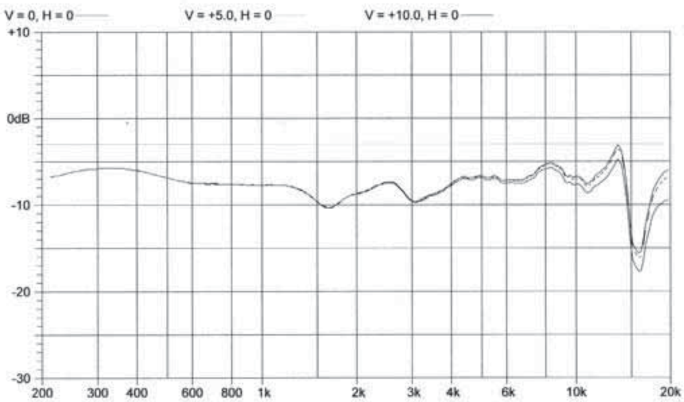


FIGURE 20: Modeled response of #214 unit B with revised crossover.

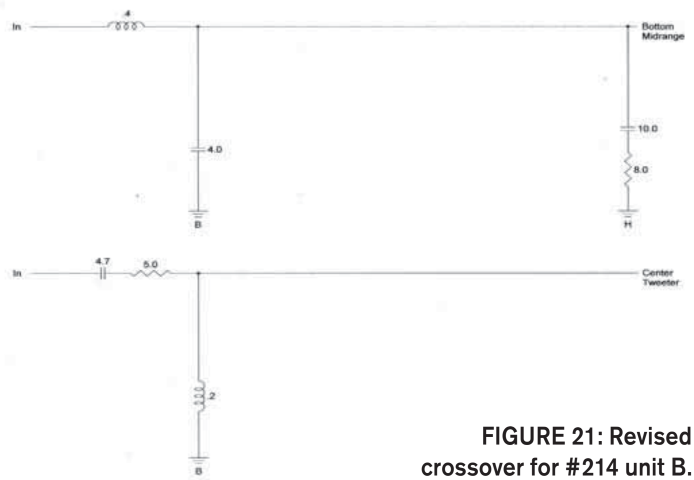


FIGURE 21: Revised crossover for #214 unit B.

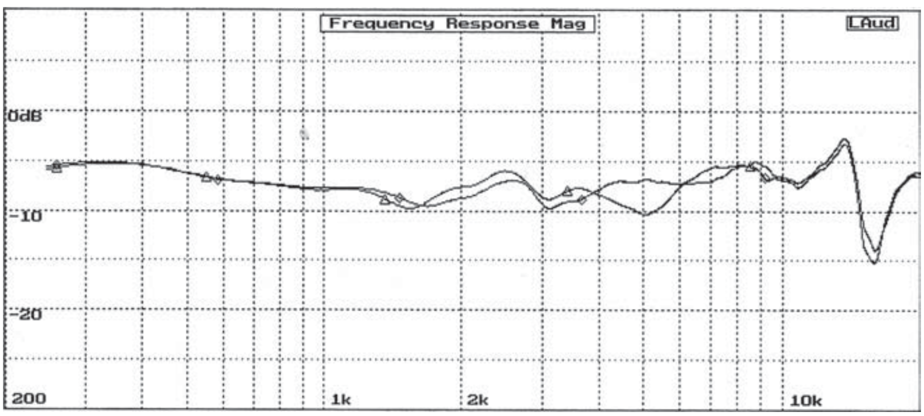


FIGURE 22: Measured response of both #214 units with revised crossover.

front width of about 9.5″. This design is for a driver CTC vertical spacing of 6.5″.

Note the modeled low-frequency response is based on a closed-box design, while a vented-box design should be superior. The performance stays consistent for listening angles of zero to +15°. This means simple construction with the coax mounted above the woofer. **Figure 26** shows the CO network used for the system with #214 unit B. For your units of this coaxial driver, you should experiment with a capacitor in series with the tweeter portion as discussed above.

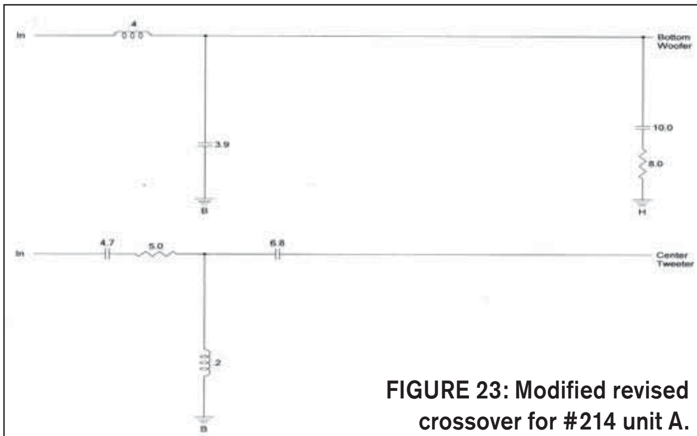


FIGURE 23: Modified revised crossover for #214 unit A.

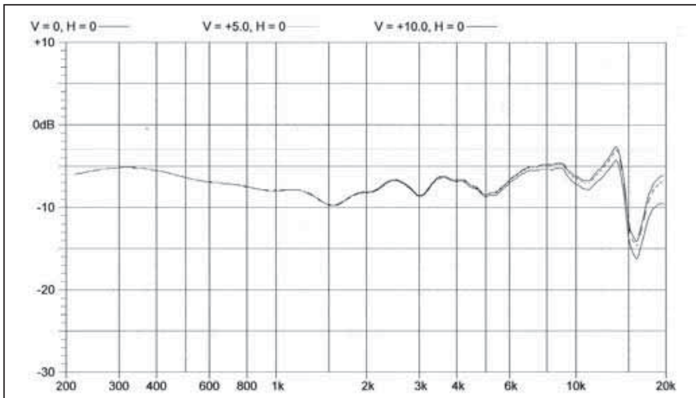


FIGURE 24: Modeled performance of #214 unit A with modified crossover.

ENTER THE W3-1364SA DRIVER

Examining the published responses for the available 3″ TB drivers, I selected the W3-1364SA unit (reference #215) and purchased a pair for testing. **Figure 27** shows the TB data for the W3-1364S driver. I could not find data for the W3-1364SA driver and do not know whether there is any major difference. **Photo 6** shows front and rear views of this driver, which uses a die-cast basket and has a fixed aluminum phase plug.

Figure 28 shows the measured performance for my pair of #215 drivers—not quite what the TB data of **Fig. 27** had led me to expect. Note that my data is with both the #215 mid/tweeter and #213 woofer mounted in the test baffle together. The presence of the woofer will roughen up the midrange response and is probably partially responsible for the wiggles in the response up to 3kHz. The roughness in this range is likely worse than displayed in **Fig. 28**, where the resolution is limited by the FFT test approach. The rising response and roughness above 3kHz is predicted by the TB response of **Fig. 27**; however, the roughness is far worse.

Remember, the FFT-based testing

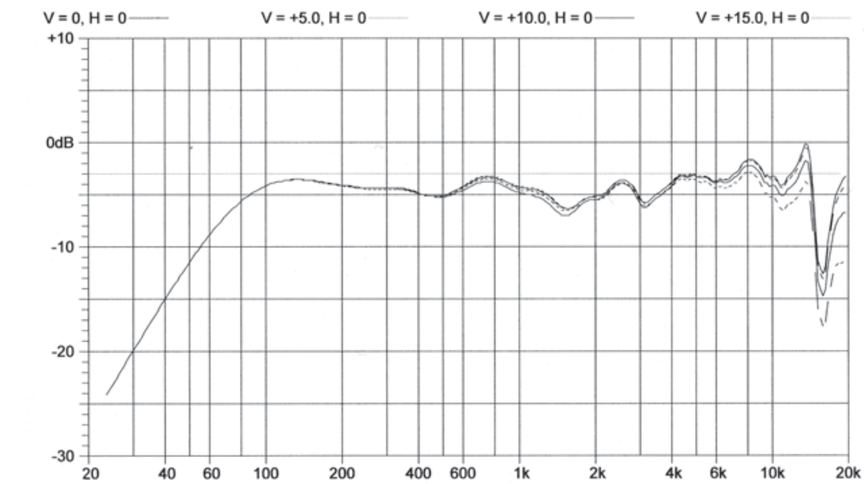


FIGURE 25: Modeled performance of system using the #213 and #214 drivers.

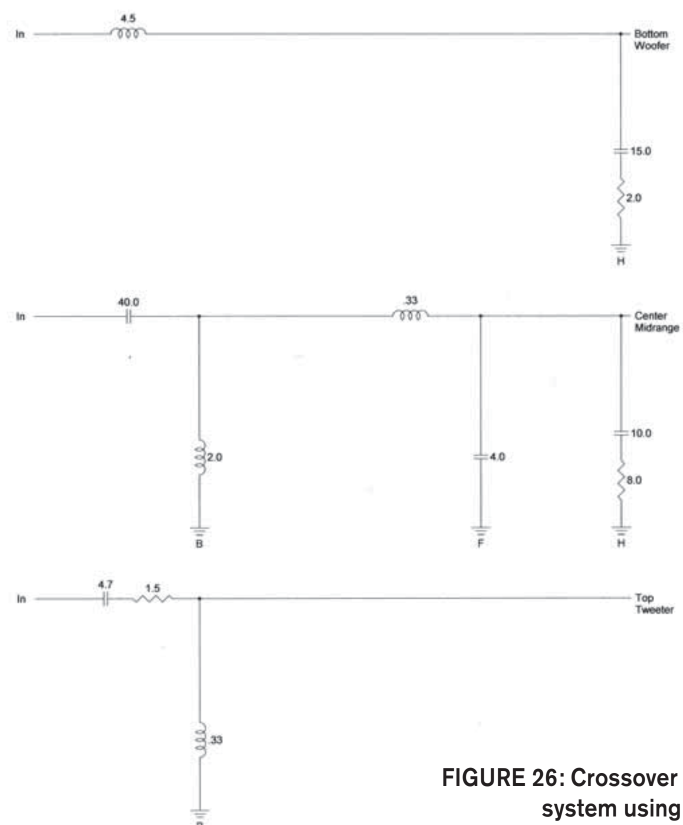
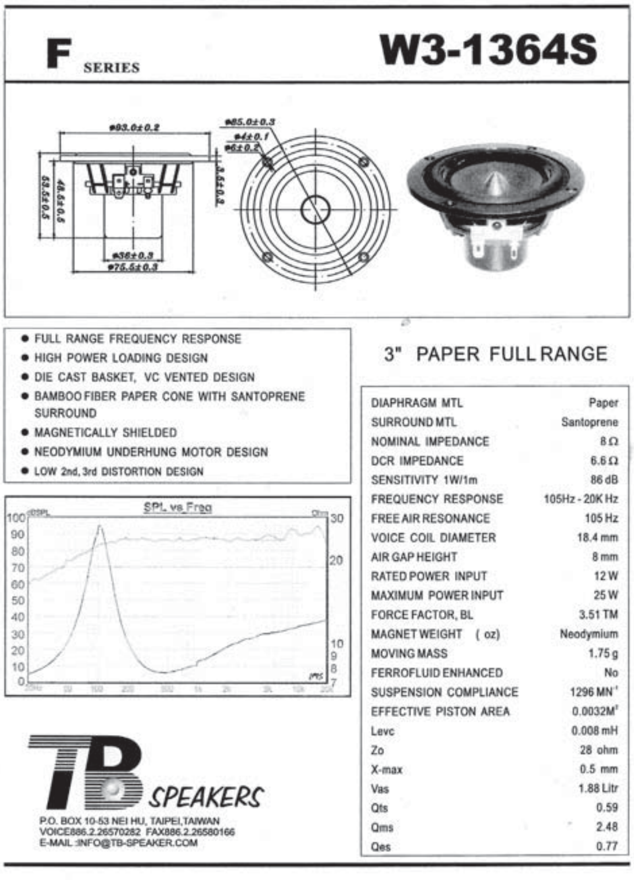


FIGURE 26: Crossover for P213 214 system using #214 unit B.



F SERIES

W3-1364S

- FULL RANGE FREQUENCY RESPONSE
- HIGH POWER LOADING DESIGN
- DIE CAST BASKET, VC VENTED DESIGN
- BAMBOO FIBER PAPER CONE WITH SANTOPRENE SURROUND
- MAGNETICALLY SHIELDED
- NEODYMIUM UNDERHUNG MOTOR DESIGN
- LOW 2nd, 3rd DISTORTION DESIGN

3" PAPER FULL RANGE

DIAPHRAGM MTL	Paper
SURROUND MTL	Santoprene
NOMINAL IMPEDANCE	8 Ω
DCR IMPEDANCE	6.6 Ω
SENSITIVITY 1W/1m	86 dB
FREQUENCY RESPONSE	105Hz - 20K Hz
FREE AIR RESONANCE	105 Hz
VOICE COIL DIAMETER	18.4 mm
AIR GAP HEIGHT	8 mm
RATED POWER INPUT	12 W
MAXIMUM POWER INPUT	25 W
FORCE FACTOR, BL	3.51 TM
MAGNET WEIGHT (oz)	Neodymium
MOVING MASS	1.75 g
FERROFLUID ENHANCED	No
SUSPENSION COMPLIANCE	1296 MN'
EFFECTIVE PISTON AREA	0.0032M'
Levc	0.008 mH
Zo	28 ohm
X-max	0.5 mm
Vas	1.88 Litr
Qts	0.59
Qms	2.48
Qes	0.77

SPL vs Freq

TB SPEAKERS

P.O. BOX 10-53 NEI HU, TAIPEI, TAIWAN
VOICE886.2.26570282 FAX886.2.26580166
E-MAIL :INFO@TB-SPEAKER.COM

FIGURE 27: Tang Band data for the #215 (W3-1364S) driver.

shows improving resolution as frequency rises. It is possible the TB plot has had smoothing applied. It is quite common for small piston drivers to show a rising on-axis response to offset the fall-off at high frequency as you move off-axis. **Figure 29** shows the measured performance of the #215 driver as you move off-axis. The high frequency always shows the roughness, but with the large piston diameter the average high-frequency response is actually falling by 20° off-axis.

It is my experience that the small TB drivers sound better than their unsmoothed response curves would lead you to expect. While I'm not a fan of high-frequency whizzers, some sound reasonably good. You would probably not even consider using them if you ever saw their unsmoothed response.

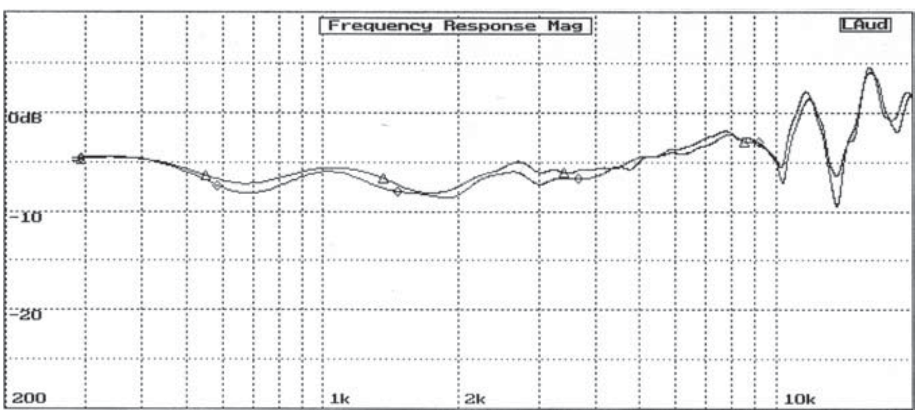


FIGURE 28: Measured performance match of pair of #215 drivers.

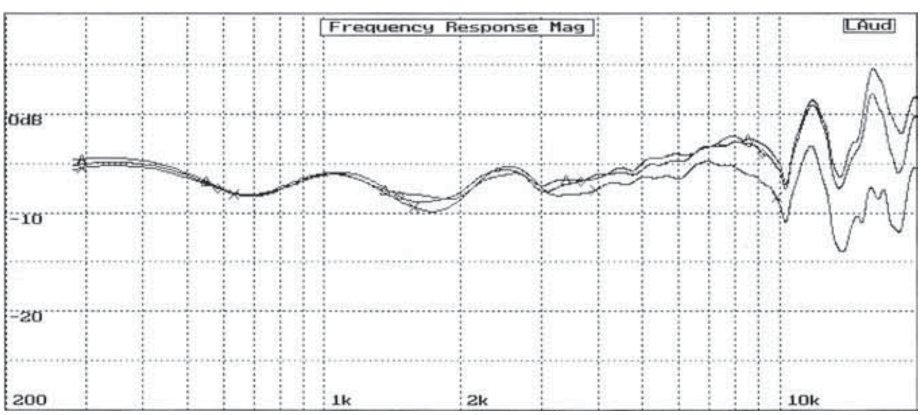


FIGURE 29: Measured off-axis performance of the #215 driver.

DEVELOPING THE P213 215 SYSTEM

I entered response and impedance files for both drivers into a CO modeling program, along with values for the effective piston diameters and offset in acoustic origins. The modeling uses a CTC spacing between drivers of 6.5″. I extended the low-frequency response of both drivers by splicing an ideal closed-box response to the measured response. This lets you include diffraction spreading loss in the modeling process. Keep in mind the modeled low-frequency response does not represent what the system will actually provide, because a closed box may not be the best enclosure. All work assumes the two drivers are flush-mounted into a flat baffle.

The system was modeled with a first-order low-pass with zobel on the #213 woofer. The #215 driver used a special second-order CO, per **Fig. 10** in Part 1, with a series R-L-C network across the driver to suppress the driver's resonance. You may need to modify the values for this network to match the final enclosure used for the #215 driver. I tried the system with CO frequencies of 600, 800, 1,000 and 2,000Hz. To me, the best system appeared to be the 800Hz CO frequency based on lobing considerations.

Figure 30 shows the modeled performance of the system with correction for 3dB of diffraction spreading loss for an enclosure width of 9.5″. Both the system phase-versus-frequency response and polar-phase plot show above 200Hz this is a near-zero-phase system over considerable vertical angle. The optimum listening angle is about –10° (i.e., 10°off the mid/tweeter axis toward the woofer). This means for floor-standing construction the woofer would be at the top with the mid/tweeter below it.

I believe the rising average response at high frequency will sound about right. If you would like to flatten the top-end response, as was done with the P180 187 system, insert a small inductor in series with the #215 mid/tweeter. **Figure 31** compares the system response without the small inductor (solid curve) to that with a 0.1mH inductor (dashed curve).

Figure 32 shows the basic schematic for the CO, which requires some pretty large inductors. Both drivers are used positive polarity, and this system should be considered a 4Ω system.

Building time ran out, so I have not yet designed this system in detail. I looked at what enclosure might be best for the #213 woofer and based on catalog data decided on a vented-box approach. A normal QB3 alignment would require a box net volume of 0.3ft^3 and tuned to f_b = 60Hz should give an f_3 around 64Hz. Pushing the small woofer into a jammed-B4 alignment would require a box net volume of 0.35ft^3 tuned to 60Hz for a slight f_3 improvement to 60Hz. For these systems, the woofer would deliver the system output above about 80Hz, with the port delivering the system output below that frequency.

Adding damping material would slightly change these numbers. The #215 mid/tweeter is not used to the bottom end of its potential response so a small closed-box enclosure would be fine. It is likely, as I found with the P180 187 system, a reasonable enclosure design leaves this closed box much bigger than it needs to be acoustically, so high damping can be used. For the P180 187 system I also placed a portion of the CO inside the mid/tweeter closed box. I have no reason to believe it would not be a good-sounding little system, as with the P180 187 project. The tip angle for the P213 215 enclosure would be a bit less than was required for the P180 187 enclosure.

SUMMARY

This article shows one way to accomplish minimum phase for small two-way systems for those who would like to experiment in that area. Based on development of two systems, it appears in general that two of the small TB drivers with considerable frequency-response overlap can be combined to produce a near-zero-phase system. While zero-phase is not considered a requirement for a good-sounding system, a minimum-phase design does assure low time dispersion.

These systems use a flat front panel, only two drivers, and a relatively simple CO network. While a 3″ cone driver is no match for a good tweeter, these inexpensive small systems can sound quite good. It is likely that pairs of small drivers with large frequency-range overlap by other manufacturers could also produce simple near-zero-phase systems.

I was not happy with the TB W3-1723 coaxial drivers and found no way to develop a minimum-phase system with them. The two units I had did not match well, and the high-frequency response did not measure much smoother than the normal coned 3″ TB drivers. They may sound better than the response curves indicate, as to date I have not heard them. My alternate CO to what TB recommends measured better with my units. Using the normal 3″drivers as a mid/tweeter greatly reduces the CO component count due to being a two-way rather than three-way system. *aX*

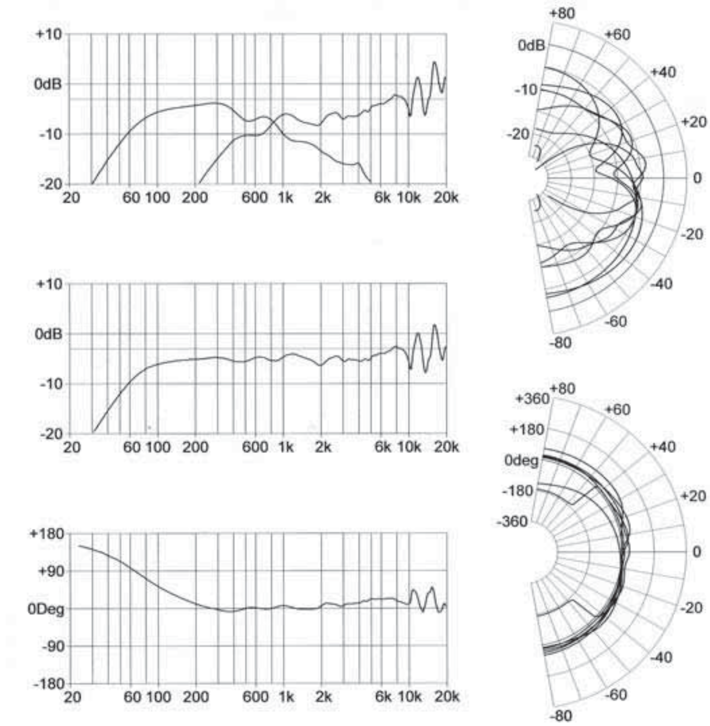


FIGURE 30: Modeled performance of P213 215 system.

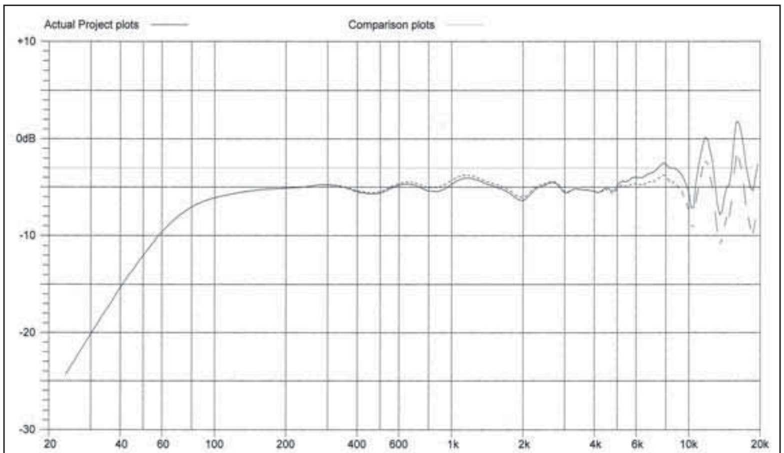


FIGURE 31: Effect of adding small inductor (solid line no inductor, dashed line 0.1mH inductor).

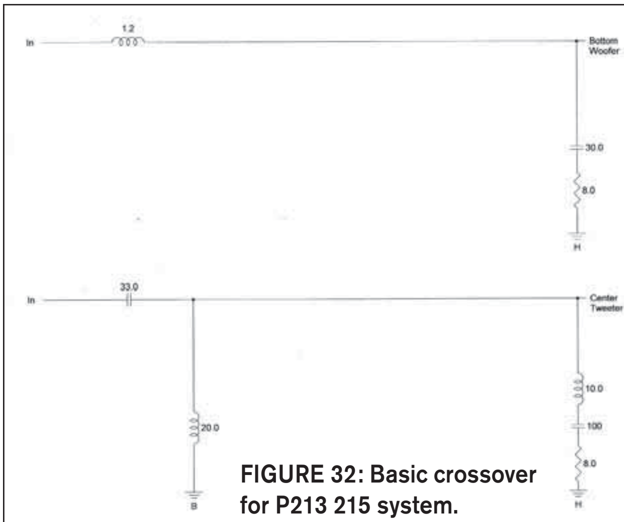


FIGURE 32: Basic crossover for P213 215 system.

VENDORS

AudioClassics.com Buys - Sells - Trades - Repairs - Appraises McIntosh & other High End and Vintage Audio Equipment 800-321-2834

Easy 50W Piccolo Gainclone amp kitset slots straight into ezPower Chassis **www.designbuildlisten.com**

High Performance kits, Audiophile components Custom designs, Custom Assembly **www.borbelyaudio.com**
In North America: LBAudio, Les Bordelon, lbordelon@roadrunner.com
In Taiwan: TS audiolab, Tai-Shen Lee, tsaudio.lab@msa.hinet.net

Ad Index

show report | By David J. Weinberg

ICES 2010—Changes Abound

Technology and economics have changed the product types and mix exhibited at the International Consumer Electronics Show (CES), more so this year than in my recollection. The usual assortment of plasma and LCD panels were touted less for image size and qualities than for wireless HDMI, Internet connectivity, direct access to streaming-video sources such as NetFlix, and 3D.

This was the CES at which the i-industry bloomed in full glory with an explosion of colorful i-skins, i-accessories, and i-apps for Apple's i-products and competitors' devices. Apple's iPod Touch and iPhone (www.Apple.com) and RIM's Blackberry (www.Blackberry.com), plus phones based on Google's Android mobile technology platform [examples: Motorola's Droid (www.Motorola.com); HTC's Nexus One (www.Google.com/phone); LG's GW620 (www.LGE.com)] have instigated an avalanche of accessories and applications from a plethora of small

and large vendors. A post-CES e-mail from the Consumer Electronics Association (sponsor of CES) announced that at the 2011 CES the iLounge pavilion "will feature the largest display of iPod, iPhone, iPad and Mac products in CES history."

Mobile-device sophistication and choices are increasing rapidly, especially in their use as remote controls for all types of home automation systems. A precipitately growing specialty within the mobile device category is ereaders, which have the text-display capabilities of a netbook or laptop in a more compact case with simpler customized controls.

The automotive exhibits showed that beyond the traditional aftermarket high-powered sound systems, cars are becoming as electronically sophisticated as a home theater—synching to home PCs and media centers for audio and video, having built-in Bluetooth and Wi-Fi, delivering independent programs at different seats, and so on. CES has become an important show for small, light laptops and netbooks plus all sorts of accessories and peripherals including microprojectors.

The consumer electronics industry has progressively recognized home health management. A larger show floor area than last year's was dedicated to products and services for home health monitoring and management.

This was the first CES where a large contingent of Asian companies exhibited products of all sorts under their own brands in the Las Vegas Convention Center (LVCC) instead of in the Hilton Hotel Conference Center next door, where they had heretofore been segregated. These changes in the exhibit mix led me to adjust the emphasis of my CES coverage.

Note: Each year, coincident with CES but independent of it, are two press-only events: Showstoppers and Digital Experience. Each has more than 100 exhibitors in a hotel ballroom, which makes learning about their products more time-efficient. Several products that I found interesting are included in this report.

An additional CES-independent press-only event is Lunch@Piero's, with just over 20 exhibitors of unusual and developmental technologies.

PRESS CONFERENCES AND EXHIBITS

The major manufacturers' press conferences covered a broader range of product types than at past shows. Convergence has matured to the degree that the word was not used; "connectivity" is the new "convergence."

Panasonic (www.Panasonic.com) talked of its "end-to-end 3D solutions" including a 3D camera, 3D Viera displays, 3D Blu-ray players, and 3D content delivered to the home through partnerships with content providers including DirecTV, which they claim will begin delivering 3D content over three 3D channels in June 2010 (a 3D display is required, plus a software download to existing DirecTV set-top boxes). They demonstrated HD-video Internet communications by having an executive talk to us live from Osaka, Japan, during the press conference. *Avatar* producer Jon Landau spoke of 3D as a "window into a world [and a] more immersive and more voyeuristic experience." IPTV provides more ways to get content to multiple devices. Panasonic has added Skype software to Viera Cast technology for video telephony. They are relaunching the Lumix brand of cameras.

Panasonic's and JVC's "press kits" were handmade paper embedded with seeds for basil and wildflowers, respectively. Plant them, water them, watch them grow.

Samsung (www.Samsung.com/us/) claimed its LED-backlit display sales earned them 80% market share in 2009, although no explanation was given of how that was measured. Samsung's focus is on the "customer experience" through "innovation, applications and connectivity." Their new multi-device app store offers an assortment of apps for mobile phones, Blu-ray players, and TVs—using an open-systems software developers kit for large-screen-TV apps. They talked of their "3D home ecosystem" comprising the TV, Blu-ray player, surround sound, and content. Certain new TV models include a processor to convert 2D video to so-called 3D imagery in real time.

Samsung's 9000-series panels come with a touchscreen remote with integrated Wi-Fi and IR technology that also can control other devices using the on-TV-screen Qwerty keyboard and buttons. It also permits watching TV on the remote while viewing a Blu-ray on the big screen. Samsung is working with DreamWorks and Technicolor to deliver content to the home.

Samsung announced mobile phones with a single-chip ATSC module that will allow reception of over-the-air (OtA) DTV; they have models for each of the major cell service providers. Their IceTouch portable media player has a transparent screen and rear panel controls, so you don't block the screen while controlling it. There are new cameras and camcorders—one with a 64GB solid-state drive (SSD). Their ePaper products support reading, sharing, and writing (including handwriting input). For content, Samsung has partnered with Google books.

Sharp (www.SharpUSA.com) has found another way to make pictures prettier: add yellow as a fourth "primary" color, which they call quad pixel (Red/Green/Blue/Yellow)—the expanded color palette can be useful for photos and Internet graphics, but is incorrect for video. Some of Sharp's displays also incorporate their UV2A technology (UV-light-based liquid-crystal photo alignment technology) "for TV beyond TV" that is claimed to "offer dramatic reduction in energy consumption" compared with cold-cathode fluorescent lamp (CCFL) backlights, although there was no explanation of how that is measured. Several new Blu-ray players feature two USB ports plus an Internet connection for RSS feeds and NetFlix streaming. Showing that they have a place in residential and industrial markets beyond home entertainment, Sharp representatives spoke of their solar cell technology, ionic air treatment, and other health-related products, plus LED lamps with "wavelength control" that enables the user to adjust the color and luminance.

FOR USE WITH TV

Toshiba (www.Toshiba.com) is "reaching out for the emotional connection to the consumers." They reported that for 2009 versus 2008 panels sold was up while revenue was down, broadband use was up, and the balance of program sources is changing toward more Internet streaming. They said that manufacturers must design products for this change for the consumers who want quality with value.

Toshiba's solution is CELL TV, which enhances the image and includes a 1TB media-server/Blu-ray-player that also delivers streaming/downloaded content wired or wirelessly (Toshiba has targeted Netflix, VUDU, CinemaNow, Pandora, and others; no comment on whether HD-video or surround soundtracks will be delivered), and videophone capability. It is based around the CELL Broadband Engine that was designed for multimedia processing and is used in advanced PCs and high-end gaming consoles.

CELL TV performs interpolated upconversion of SD video, applies noise reduction to Internet-sourced video, produces so-called 3D images from 2D video, and in some models uses 512 LEDs to backlight the 1920 × 1080 display (which calculates out to one LED for each 4050 pixels—a square of about 64 × 64 pixels). Toshiba's new Blu-ray players still require consumers to add their own ≥1GB SD or SDHC card for BD-Live support.

TV Ears (www.TVEars.com), a manufacturer of doctor-recommended TV listening solutions, announced a "senior-friendly" 32″ LCD TV ($1200srp) with built-in wireless audio transmitter and headset, automatic shutoff (if volume and channel have not been changed for four hours), a color-coded remote, extra-large on-screen text, and the company's "white glove" specialty service that includes delivery (with complete hookup, programming and one-on-one instruction) and a toll-free phone number for assistance.

Da-Lite (www.Da-Lite.com) hosted Joe Kane projecting the most accurate images at the show from the Joe-Kane-endorsed Samsung SP-A900B single-chip DLP projector ($13,000srp from www.DVEDist.com) onto Da-Lite's JKP Affinity screen, which was developed in conjunction with Joe Kane Productions (www.VideoEssentials.com).

Hillcrest Labs (www.HillcrestLabs.com) introduced the Loop Pointer ($100srp), an in-air mouse for TV that lets users who connect their PC/Mac to their TV "control an on-screen cursor with the flick of the wrist." The Loop Pointer is based on Hillcrest Lab's Freespace technology and uses RF communication so line of sight to the computer is not necessary.

ThinkOptics (www.ThinkOptics.com), which believes that "now it's OK to point," has the Wavit family of free-space pointing devices that provide mouselike functions when used with a TV screen fed from a PC/Mac. There are two versions: the Wavit (www.Wavit.com; $70/$80), a stylish 10-button learning/blasting remote; and the iWavit (www.iWavit.com; price TBA), an attachment for the iPhone.

New Kinetix (www.NewKinetix.com) announced the Rē remote control accessory and app ($70srp) for the iPod Touch and iPhone that makes it a universal remote.

L5 Technology (http://L5Remote.com; a Showstoppers exhibitor) showed a prototype L5 remote accessory and app for the iPhone and iPod Touch that turns it into a universal learning remote. It learns the command codes from your other remotes, and you program the app with your choice of buttons with customized names.

Amulet Devices (www.AmuletDevices.com) has released the Amulet remote for the Windows Media Center that has buttons but offers the ability to use voice commands and gestures.

No Geek Needed's (www.No-GeekNeeded.com; a Showstopper exhibitor) Video Grabber ($50srp) claims to be a simple cables/software solution for converting videotape recordings into DVDs or files on your disc drive.

ADVANCED AUDIO

Fraunhofer Institute for Integrated Circuits (IIS) audio and multimedia group (www.IIS.Fraunhofer.de/EN/bf/amm/) has been working in compressed audio and multimedia for more than two decades and is credited with initial development of the MP3 codec, as a codeveloper of the Advanced Audio Codec (AAC), and continues to be involved in generating MPEG surround technology standards. Matthias Rose said that under a European-Union-funded project they have developed technology that delivers HD-video with CD-quality-audio Internet teleconferencing, using the catch-phrase: "Together anywhere, together anytime." Their claim is "to be able to forget about the distance and talk to friends and family as if they were in the same room."

The technology reduces room echoes normally heard from speakerphones, includes voice tracking to retain stereo sound imaging to match the video, and exhibits a short time delay to minimize the sense of a remote communication. Their technology is included in Cisco TelePresence (www.VuTelepresence.com) models and other products. A full demonstration will be given at IFA-Berlin (3-8 September 2010; www.IFA-Berlin.com).

Consumer Lifestyle News (www.CLN-Online.org) "is Europe's web-based information hub for professionals of the consumer electronics and home appliance sectors, working closely with the main European industry associations."

HDMI Licensing (www.HDMI.org) offered information about the HDMI specification v1.4 (released 5 June 2009), which adds an Ethernet channel (up to 100Mbps Ethernet to the STB or display, then through HDMI to the other devices such as the Blu-ray player or surround processor), an audio-return channel (to get sound from the display back to the surround processor), and support for 3D video. It also increases the maximum video data rate to handle up to 4096 × 2160/24p (approximately Digital Cinema's 4k resolution), enables real-time signaling of content type between display and source devices (enabling the display, if capable, to auto-optimize picture settings for that content; requires metadata in the content data stream), adds color spaces used in digital photography and computer graphics (not applicable to SD or HD video), and includes specifications for the smaller HDMI micro-connector as well as cables/connectors for automotive connections. None of this is needed for OtA, satellite, cable system, or DVD/Blu-ray video at any of the currently used resolutions or frame rates.

Monster (www.MonsterCable.com) was 30 years old last year. At this year's press conference founder Noel Lee announced that Monster is "kicking off the next 30 years" with such products and promotions as a lifetime-guaranteed free upgrade on certain HDMI cables (if you ever need more HDMI-cable bandwidth due to technology advances), having cables speed-tested by Simplay Labs (www.SimplayLabs.com), a Blu-ray demo disc, power centers, a universal A/V-system/lighting remote, and the Turbine Pro in-ear monitors ($400srp) with a one-time no-questions-asked replacement guarantee. The Wham-Bam! is Monster's "ultimate high definition experience" Blu-ray demo disc, created in conjunction with Sony Music, Universal Studios Home Entertainment, Walt Disney Studios Home Entertainment, and THX; it includes movie demos and THX Optimizer setup material.

George Benson's Songs and Stories album, produced by Monster Music and the Concord Music Group, also has been released as a High-Definition Surround Sound SuperDisc (playable on any DVD player; surround audio in 24/96 DTS at 1.5Mbps and 448kbps Dolby Digital), available at Best Buy ($25srp); the disc contains digital music files (192kbps WMA and 320kbps AAC) encoded in Dolby Headphone Surround. Monster acknowledged the i-market with their iPod and iPhone car chargers and FM transmitter.

NXT (www.NXTSound.com) continues expanding the market for its distributed-mode speaker technology to panel displays, soundbars, car speakers (including the roof liner speaker system in certain Toyota Tacoma models), and laptops/netbooks (where the screen is the stereo speaker system). NXT-technology-based soundbars for laptops include the Insignia soundbar ($35srp; available at Best Buy) and the iDesign Sound-

bar ($40srp from Brookstone). The TuneBug (www.TuneBug.com) Shake and Vibe deliver sound by vibrating a surface including a motorcycle helmet or a window pane. A new application is NXT's haptic touchscreen technology called TouchSound, which supports multitouch actions and provides tactile feedback from the touchscreen surface even while functioning as a speaker.

Klipsch's (www.Klipsch.com) new product is the LightSpeaker, developed by Kadence Designs, which combines LED lighting and wireless background audio into a single unit that screws into the light-bulb socket in most 5-6″ recessed light fixtures. The 10W LED lamp generates the equivalent light of a 65W incandescent bulb and is dimmable using its remote that also controls sound level. Two music sources can be connected to the standalone transmitter that uses proprietary 2.4GHz wireless technology to deliver audio to up to two independent zones. The speaker is driven by a

20W switch-mode amp in the LightSpeaker module. A bundled package of two LightSpeakers, transmitter, RF remote, mini-jack-to-RCA-plugs cable, lenses and trim costs $600srp; each additional LightSpeaker module costs $250srp.

Etymotic Research (www.Etymotic.com) introduced several in-canal earphone models that deliver sound quality close to its ER4 reference at a lower price. The mc3 (moving-coil driver; $100srp), hf2 and hf3 (both balanced-armature designs like the ER4; $180srp) include a mike module along the cord with controls that allow switching between music listening and phone communication. The hf5 ($150srp) is the same as the hf2/hf3 without the mike. There are two EtyBLU2 Bluetooth models (with and without removable boom; $130srp).

Audio-Technica (www.Audio-Technica.com) announced the ATH-ANC25 QuietPoint active noise-canceling on-ear headphones ($100srp), which aren't quite as effective as the ATH-ANC7b ($220srp) but offer many of the same features including the ability to use them as headphones even with dead batteries.

Yurtopia (www.YurBuds.com) launched Yurbuds earbud enhancers ($20srp), which are soft rubber tips that slip over consumers' existing earbud-style headphones (adapters are available for other earphone designs). Yurtopia also debuted its iPhone app that allows consumers to "get fitted" anywhere using their iPhone to take a picture of their ear (with a quarter adjacent to the ear as a measurement reference) and submit it with their order.

CAR ELECTRONICS

The increasing number of electric/hybrid cars and the growing integration of complicated electronic systems and controls has driven the automotive electronics market to be more upscale and interconnected with home systems. One example is Continental Automotive's (www.Continental-Automotive.com) AutoLinQ that runs on Google's Android OS and can be customized by car or aftermarket manufacturers to "bring everything together—your car, your home, your lifestyle, your entertainment"—because it connects cars to portable devices, media applications, and other systems via a haptical, graphical, or voice-controlled interface.

Kia Motors (www.Kia.com) exhibited a car to show off their implementation of its "UVO in-car infotainment system" ("co-developed with, and powered by, Microsoft"). The UVO uses voice recognition, touch-panel and haptic-steering-wheel controls of its intelligent jukebox, bluetooth phone connectivity, HD radio, rearview camera, automotive diagnostics, automatic crash notification, point-of-interest download to GPS, OtA DTV, plus access to web content and social network services. With all of that distraction, I don't know when the driver has time to drive.

Kenwood (www.KenwoodUSA.

com) showed that even car electronics have adopted i-style finger-swipe scrolling. Their products include Parrot (www.Parrot.com) Bluetooth, i-connectivity, plus multimedia content management and distribution throughout the vehicle. They have partnered with Garmin and Navteq to provide map updates for life with no annual subscription fee.

Pioneer (www.PioneerElectronics.com/PUSA/) talked only about mobile products at their press conference, touting their Platform for Aggregation of Internet Services (PAIS) that is designed to interconnect the home and automotive systems. Pioneer has opened up PAIS for use by other manufacturers, facilitating integration of multiple vendors' products. PAIS puts one device in the car that delivers many services, some under voice control. They made no statement regarding compatibility with factory-installed original equipment or how they can replace the original equipment that is often extensively integrated into a car's operation.

ProClip (www.ProClipUSA.com) offers easy-to-install car mounts for all sorts of portable devices including GPSes, PDAs, cellphones, and i-players. The company has been in business for about 35 years and provides mounts for taxis, police vehicles, and now the rest of us. None of the mounts require screws or in any way damage the vehicle's interior; they are clip-ons that latch into the seams of the dash or console.

Spotlight ($20srp; www.12VSpotlight.com) is a cleverly designed compact rechargeable-NiMH 0.5W-LED flashlight that plugs into your car's cigarette lighter socket for charging. It is claimed to deliver 25+ lumens and run for more than three hours on a charge. Available accessories include a wall-wart charger (the Home Helper kit is $35srp including the Spotlight).

ACCESSORIES AND MORE

For kids of all ages, Lego Universe (www.LEGOUniverse.com) "is the first massively multiplayer online game (MMOG) for LEGO fans. It's a giant online world where players from all over Earth can safely build, play and pal around together."

Maxthon (www.Maxthon.com; a Showstoppers exhibitor), developed in China, is claimed to be "the world's sixth most popular browser, just 0.05% behind the browser Opera."

Contour Design's (www.ContourDesign.com) RollerMouse Free ($220srp) is a roller bar plus seven buttons that enables you to perform all mouse functions without taking your hands off the keyboard (a functionality I have sought for 30 years). The roller-bar/wristpad is placed just in front of the keyboard. Either thumb can easily roll the bar (for scrolling) while simultaneously sliding the bar sideways. Slight pressure on the bar or on the left button operates as a left click. Holding the bar down while rolling/sliding it is equivalent to holding down the left mouse button while moving the mouse.

The first time I saw a roller bar was more than 20 years ago on a GRiD laptop; it was crude and didn't work very well. This one works too well. The motion is exceptionally fluid. I wish there was more resistance to its motion because I find it tricky to quickly position the cursor accurately and hold it in place while I press the bar. A scroll wheel and other buttons provide other functions, two of which are for copy and paste; however, on a Mac they select, but don't adjust, the audio level, a problem the company is working to fix.

Seal Shield (www.SealShield.com) offers dishwasher-washable keyboards, mice, and TV remotes for those of us who can't keep our food and soda far enough away. Several keyboard models can be rolled up for compact storage and transport.

DisplayLink (www.DisplayLink.com) is a chip and software company whose technology is used in a wide assortment of docking stations plus monitors, projectors and USB graphics adapters (such as the DL195 Display Port to DVI adapter).

Promise Technology's (www.Promise.com) gold T-shirt drew attention to their SmartStor Zero home network storage and digital media server device, which supports Digital Living Network Alliance (www.DLNA.org) compatibility. The T-shirt sports on its front a head-drawing of Albert Einstein with the formula E=PS2 and on the back the lame explanation (Entertainment = Promise Storage Squared).

Victorinox (www.VSACorporate.com or www.SwissArmy.com) has expanded its SwissFlash series to 30 models ($31-$155srp) in configurations including removable flash drives up to 32GB, two finishes, a laser pointer, and some without knife blades that have TSA approval for airplane carry-on. They also offer flash models that incorporate biometric fingerprint-sensor security, plus the Presentation Master that includes a Bluetooth remote and laser pointer.

Thermapak (www.Thermapak.com) has expanded its line of effective heat-shift laptop pads and bags, along with their upgrade program.

Toktumi (www.Toktumi.com) announced Line2, a dual-mode iPhone calling app that lets you place calls over Wi-Fi when available, otherwise over the cell network.

GetJar (www.GetJar.com) claims to be the "world's largest cross-platform app store," offering "appsolutely everything" and boasting "over a half billion downloads to date."

FlyCast (www.FlyCast.FM; a Showstoppers exhibitor) is a free mobile broadcast network that offers choices among more than 2000 channels of music, talk radio, sports, and terrestrial radio stations nationwide. The service works with Macs/PCs and smartphones including the iPhone and iPod Touch, Android-based phones such as the Motorola Droid and G1, and several Blackberry models.

Speck (www.SpeckProducts.com) designs and makes cases, shells, sleeves, bags and packs for laptops, ereaders, PDAs, and i-products. They have contracted with ArtsProjekt (www.ArtsProjekt.com) for some of their artistic case designs.

Case-Mate (www.Case-Mate.com) takes artistic i-case design one step further, letting you remix "the designs of internationally renowned graphic artists" (www.IMakeMyCase.com).

iaPeel (www.iaPeel.com) is a source of inkjet-printable iPod skins (starter kit of skins and software is $30srp) for the iPod Classic, Nano, Touch, and the iPhone. Use their software to design your own skin, then print it on the blank.

XTremeMac (www.XtremeMac.com) announced the InCharge series of home and travel charger models and the Microshield Mix series of cases for Mac and i-products.

Franklin Electronic Publishers (www.Franklin.com), known for their organizers plus portable dictionaries and games, now distributes Swiss Travel's SK Ross (www.SKRoss.com) World Travel Adapters, including the Micro Mobile phone charger with retractable cable and several phone connector tips, and the World USB charger that comes with an iPod power cable.

Powermat (www.PowerMat.com) followed up on last year's introduction with an expanded line of wireless charging mats. The mat, which can charge multiple devices, plugs into the wall outlet. After replacing the portable device's battery with a custom rechargeable module from Powermat, placing the device on the mat will recharge it, eliminating the need to plug in a charger. They offer receiver/cases for certain PDA and phone models that add the wireless charging capability without replacing the internal battery.

YoGen's palm-sized universal mobile-device charger ($40srp; www.YogenStore.com) is clever. Pulling the cord drives the alternator to generate output at the mini-USB port. Each of the four models includes the YoGen charger, a cable and connecting tips for a different family of devices.

PowerGenix (www.PowerGenix.com; a Lunch@Piero's exhibitor) demonstrated its nickel-zinc (NiZn) rechargeable batteries that are claimed to "offer more power, higher performance and quicker recovery time than that of [other rechargeable] AA batteries in high-drain devices like digital cameras." Their batteries charge to 1.6V (versus typical NiCd and NiMH that charge to ~1.2V) and are nontoxic and noncombustible. PowerGenix claims a higher watt-hour capacity for the same size cell than NiCd or NiMH cells, although not as high as Li-ion cells. They also claim lower internal resistance, resulting in less voltage and power loss at higher current-drain levels. It is necessary to use PowerGenix's charger, because their NiZn batteries cannot be charged properly in a NiCd or NiMH battery charger.

DMC Worldwide (a Digital Experience exhibitor) introduced COPIA (www.TheCOPIA.com), "an open platform that combines content, social networking, collaboration and e-commerce with an array of wireless e-Readers," plus a line of six ereaders.

Books, magazines, newspapers, and other digital content are offered for reading on ereaders, notebooks, netbooks, tablets, and smartphones.

Spring Design (www.SpringDesign.com; a Lunch@Piero's exhibitor) unveiled Alex, a dual-screen Android-based ereader that integrates web browsing and e-mailing on its 3.5″ screen while displaying reading material on its 6″ epaper display (EPD) screen.

Jay Johnson is an inventor (dba Ctesibius; www.Ctesibius.com; a reference to the Greek inventor/mathematician in Alexandria, Ptolemaic Egypt, 285-222 B.C., possibly the first director of the museum at Alexandria) who has developed the Cord Cruncher, a clever elastic sleeve for earphone and other thin cords that offers compact storage and complete freedom from tangling. Johnson seeks earphone/headset manufacturers to put this on their cable products; I hope they do.

ShopJimmy (www.ShopJimmy.com) is an online supplier of replacement TV and appliance parts, focusing on rare and no longer available parts.

One example of the Asian pursuit of retail markets is the Hong Kong Trade Development Council (www.HKTDC.com), which provides "a trusted online sourcing platform that connects more than 120,000 credible suppliers verified by renowned authentication companies."

OVERVIEW

There was a contrast among the huge exhibits (such as LG's, Samsung's, Intel's, Microsoft's, Panasonic's and Sony's), with many booths smaller than in previous years, no exhibits in the Sands Convention Center, and a surprising amount of clear floor space in the LVCC. The preshow estimate of 2500 exhibits is down from last year's 2700.

Press attendance seemed much higher than last year's, and CEA estimated more than 5,000 press, bloggers, and analysts.

Preliminary overall attendance, including exhibitor personnel, was claimed to be approximately 120,000, about 10,000 more than last year's preliminary count. A CEA representative said that these numbers come from counting the badgeholders given out at the show (even a preregistered attendee must pick up his badgeholder at the show).

Unlike last year, when on Sunday (the show's last day) the show floor was deserted except for a few of us and those who had to staff their booths, this year the show floor was moderately busy during all four show days. Perhaps more attendees came only for the weekend days than last year. aX

Oppo BDP-83 Blu-ray Disc Player

by Gary Galo

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The Oppo brand of audio/video components seemed to emerge out of nowhere a few years ago. Their DV-980H Universal DVD Player has received extremely favorable reviews in various high-end A/V publications (*aX* Dec. 2009), and, having heard the player myself, I can attest to its remarkable performance for the asking price of $170. The DV-980H is a multi-format player that handles regular CDs, SACDs, DVD-Video and DVD-Audio, and outputs full 1080p high-definition video via an HDMI 1.2A output and 7.1 channel surround outputs.

UNIVERSAL REDEFINED

Technology never stands still for long, and the Blu-ray format has re-defined the terms "multi-format" and "universal." But, so far, equipment manufacturers have been slow to offer universal players that support the Blu-ray format. Denon introduced the first universal Blu-ray player last year, but the $4500 list price of their model DVD-A1UDCI put it out of the reach of most consumers. Denon's website notes that the DBP-4010UDCI universal player, priced at $1999, is "coming soon" (www.usa.denon.com).

Marantz's new flagship universal player, the UD9004, carries a list price of $6000 (us.marantz.com). Cambridge Audio has announced a universal Blu-ray player, the Azur 650BD, which they say is "coming late 2009" (www.cambridgeaudio.com). Audio Advisor just posted this unit at a list price of $779 and a selling price of $699 (www.audioadvisor.com).

Oppo's latest product is a serious attempt to break the cost barrier (**Photo 1**). The BDP-83 Blu-ray Disc Player is a true universal player, supporting all of the active 4¾″ optical formats, including Blu-ray, DVD-Video, DVD-Audio, CD, SACD, and HDCD. The BDP-83 will also play AVCHD discs (a high-definition video camera format that uses data compression), but it will not play obsolete formats such as HD-DVDs.

The Oppo player also supports Kodak Picture CD, plus standard audio/video/picture files on recorded discs, including MKV (Matroška, a multi-media format; see www.matroska.org). The BDP-83 has two USB ports, allowing USB drives with media files to be played back through the BDP-83. The USB ports can supply 5V at up to 500mA to devices that are powered by the port. This should be sufficient for flash memory cards and USB thumb drives, but USB hard drives may draw more current. Oppo recommends using the hard drive's own external power supply. Audio files supported by the Oppo include .MP3, but not .WAV files.

The BDP-83 has all of the features that users have come to expect from Blu-ray players, all accessible via the remote control (**Photo 2**). Basic player operations include Fast Playback, Pause and Frame-by-Frame, Slow Playback, Blu-ray disc Menu Playback, DVD Menu Play-

PHOTO 1: Front view of the Oppo BDP-83 universal Blu-ray disc player. This attractive product boasts a brushed, anodized aluminum front panel, a refreshing departure from the plastic found in most affordable players.

PHOTO 2: The BDP-83's remote control is full-featured, easy to use and nearly non-directional. It doesn't need to be pointed directly at the player in order to operate.

back, On-Screen Display, Volume, Mute, Audio Language and Track Selection, Subtitle Selection, Angle Selection, Picture-in-Picture, Secondary Audio, and BD-Live™. For BD-Live™ the Oppo supports "Profile 2" and contains all necessary hardware, including the audio/video decoder, Ethernet port, and 1GB of internal storage. Advanced operations include TV System Selection (NTSC or PAL), Output Resolution, Zooming and Aspect Ratio Control, Zoom Levels for HDMI and Component Video Outputs, Selection Repeat, Shuffle and Random Playback, Playback by Chapter or Track Number, Playback from a Specific Location (which can be done on DVD, Bluray, CD and SACD discs), Memory and Automatic Resume, Viewing Pictures on DVD-Audio Discs, and Pure Audio Mode (which turns off the video processing for audio-only playback).

The Zooming and Aspect Ratio feature allows, among other things, a 4:3 NTSC picture to fill the entire 16:9 screen. This feature, found on nearly all HDTVs and Blu-ray players, stretches the picture horizontally, which causes distortion in the picture. People look shorter and wider than they actually are. Most HDTV owners seem to like this because they believe they're getting their money's worth when every picture fills the entire screen. I don't, so I'm glad this feature is user-selectable.

I feel the same way about this as I do about converting mono recordings into electronically reprocessed stereo—it's a falsification of the original. I don't like a distorted TV picture, so I always watch 4:3 pictures in their native mode, which places borders on the sides of the screen. The BDP-83's setup menu allows you to replace the black borders with various shades of gray, which is helpful for preventing burn-in on plasma TVs (my Panasonic plasma TV also allows you to make the borders gray).

The HDMI output supports all of the standard audio formats currently in use, including stereo, up to 7.1-channel high-resolution PCM, up to 5.1-channel DSD, plus bitstream or LPCM conversion of Dolby Digital, Dolby Digital Plus, Dolby TrueHD, DTS, DTS-HD High Resolution Audio, and DTS-HD Master Audio. The remote control is very easy to use, and is nearly non-directional—you can point it practically anywhere in the room and it will work. This makes it much easier to operate than remotes that must be pointed directly at the player.

The BDP-83 defaults to the auto-start mode for audio discs, but you can disable this in the setup menu. I prefer to manually start audio discs, but the BDP-83 has one operational quirk that I found a little annoying. When playing a CD or SACD, you can't select any track on the disc when the disc is stopped. The disc must begin playing track 1 before you can select other tracks. I'm sure this could easily be changed in a firmware upgrade.

UNPACKING AND CONNECTING

The BDP-83's packaging belies its price (**Photo 3**). The player itself is packed in a cloth tote bag that you'll certainly find useful elsewhere, once the player is permanently installed in your system. The supplied accessories include the remote control, a good-quality 6′HDMI cable, standard stereo audio and composite video cables with RCA connectors.

The RCA cables are definitely the throwaway type, but they'll get you started if you don't have anything else. You probably won't use the composite video cable, anyway (who would buy a Blu-ray player to view on an NTSC television?), and you'll surely want higher-quality audio cables. The audio performance of this player is certainly good enough to warrant high-performance cables.

The power cord is another pleasant surprise. Most DVD and Blu-ray player manufacturers supply an 18AWG, or, if you're lucky, a 16AWG power cord, even with very expensive players. The $499 Oppo comes with a 14AWG cord. The accessories are packed in a separate black rectangular box with an attractive matte finish and silver Oppo logo.

The BDP-83 has all of the standard

PHOTO 3: The Oppo player is nicely packaged, and shipped in a cloth tote bag. Accessories are packed in the matte-finished box seen at the bottom of the photo.

PHOTO 4: Rear view of the BDP-83 player. Analog connections include eight RCA jacks for 7.1-channel surround and two for stereo. The unit also has optical and coax digital outputs, HDMI, component and NTSC composite video connectors, plus a Cat-5E LAN connector.

connections you'd expect to find in a multi-format player (**Photo 4**). There are a total of ten audio output jacks: eight for the 7.1-channel surround outputs, and two for straight left and right stereo. Both S/PDIF coax and Toslink optical digital outputs are included, which operate at 48, 96, or 192kHz, user-selectable in the setup menu.

The setup menu also allows you to select linear PCM (for CDs and DVD-Audio sources fed to an outboard DAC), or bitstream (for decoding Dolby Digital or DTS through an A/V receiver). The digital outputs can't pass DSD data streams and will mute when SACDs are played. The HDMI connector will output the DSD data stream, but you may have difficulty finding an outboard DAC that accepts DSD. The Oppo player does not upsample CDs to higher sampling rates, but you can certainly do that with an outboard DAC.

A/V outputs include NTSC composite, component, and, of course, HDMI (you can connect the HDMI output to a DVI TV or monitor input, with an appropriate adapter cable). The BDP-83 also has a standard Cat-5/5E computer network connector, which facilitates firmware upgrades and also supports Blu-ray's BD-Live feature. BD-Live feature included on some Blu-ray discs allows access to extra downloadable content and online interactive programs.

The USB ports allow the connection of external computer storage devices so audio and video files stored on those devices can be played through the BDP-83. There's also a pair of 3.5mm (1/8″) stereo mini jacks for infrared remote control of other Oppo devices, such as Oppo's HM-31 HDMI switch. Finally, there's a standard, ungrounded IEC power connector, compatible with grounded IEC cords. The connection diagrams in the manual are clear and straightforward.

Oppo has two setup options for the BDP-83, an Easy Setup Wizard that allows access to the most common options, and a full Setup Menu that allows access to all of the player's setup options. If you are experienced with DVD players, you'll probably prefer to go directly to the full Setup Menu. Most of the choices are self-explanatory for experienced users, and some of the options will be necessary in order to get the best performance out of your player. These include selecting stereo, multi-channel, or CD layer default for SACDs, the DVD-Audio program default for discs that have both DVD-Audio and Dolby Digital, DTS or PCM DVD-Video programs, and the type of data sent to the digital output (LPCM or Bitstream). If you have an outboard D/A converter for PCM sources, you'll want to change the digital output to the highest sample rate your converter will support (the default is 48kHz).

Oppo also allows you to listen to SACDs in their native DSD mode (direct conversion to analog of the DSD data stream), or with an intermediate conversion to PCM before D/A conversion. This option also determines which data stream is sent over the HDMI cable—DSD or PCM (HDMI version 1.1 only supports PCM; 1.2a also supports DSD). Apparently some listeners prefer the sound of SACDs with the DSD to PCM conversion, though I can't really imagine why. Oppo describes this as preferring "straight DSD to analog," which is not correct. Neither PCM nor DSD are analog until they've passed through the D/A converters.

Perhaps they believe that the PCM conversion produces a more "analog-like" sound, though I really don't agree. With first-rate DSD D/A converters SACDs sound best when the D/A conversion is done with the data stream in native DSD mode (in my opinion, of course). But, many users will no doubt be pleased that Oppo has given them a choice. Strangely, the S/PDIF output doesn't function on SACDs even when the PCM conversion has been selected.

The BDP-83 lacks nothing in video setup choices. Like many Blu-ray players, the Oppo also has advanced video setup features for televisions that support them, including 24-frame video for movies, plus 30-bit and 36-bit Deep Color support via the HDMI v1.3 output. The player is well constructed and robust, weighing over 11 pounds. The chassis is all metal, and the brushed, anodized aluminum front panel is a refreshing departure from the plastic often found on players in this price range.

CIRCUIT DETAILS

The D/A converters, analog circuitry, and associated power supply regulators are located on their own PC board, which is mounted component-side down (**Photo 5**). I carefully removed the mounting screws and turned the board right-side up to identify the main active devices (**Photo 6**). The BDP-83 uses two D/A converter chips manufactured by Cirrus Logic (www.cirrus.com). The 7.1 channel outputs are converted with a Cirrus Logic CS4382A, a 192kHz/24-bit chip with a dynamic range of 114dB and THD+N of -100dB.

The CS4382A features advanced multi-bit Delta-Sigma architecture for PCM processing, and also supports Direct-Stream Digital (DSD) for SACDs. For DSD, the CS4382A has a proprietary DSD processor that allows for 50kHz on-chip filtering without an intermediate decimation stage. The CS4382A provides digital de-emphasis for early CDs mastered with Red Book pre-emphasis. The dedicated two-channel stereo outputs use Cirrus's flagship CS4398, a stereo-only DAC with a dynamic range of 120dB and THD+N of -107dB. This top-of-the-line 192kHz/24-bit chip is also based on Delta-Sigma architecture, with support for DSD and Red Book de-emphasis.

Analog circuitry with output filtering is built around 5532 op amps, but, like the Benchmark DAC-1 (reviewed in *aX* 1/09), Oppo has chosen Texas Instruments devices rather than the familiar JRC/NJR chips used in so many Far-East products. Both Cirrus Logic DACs have only voltage outputs. The 7.1 channel outputs are each fed to half of a

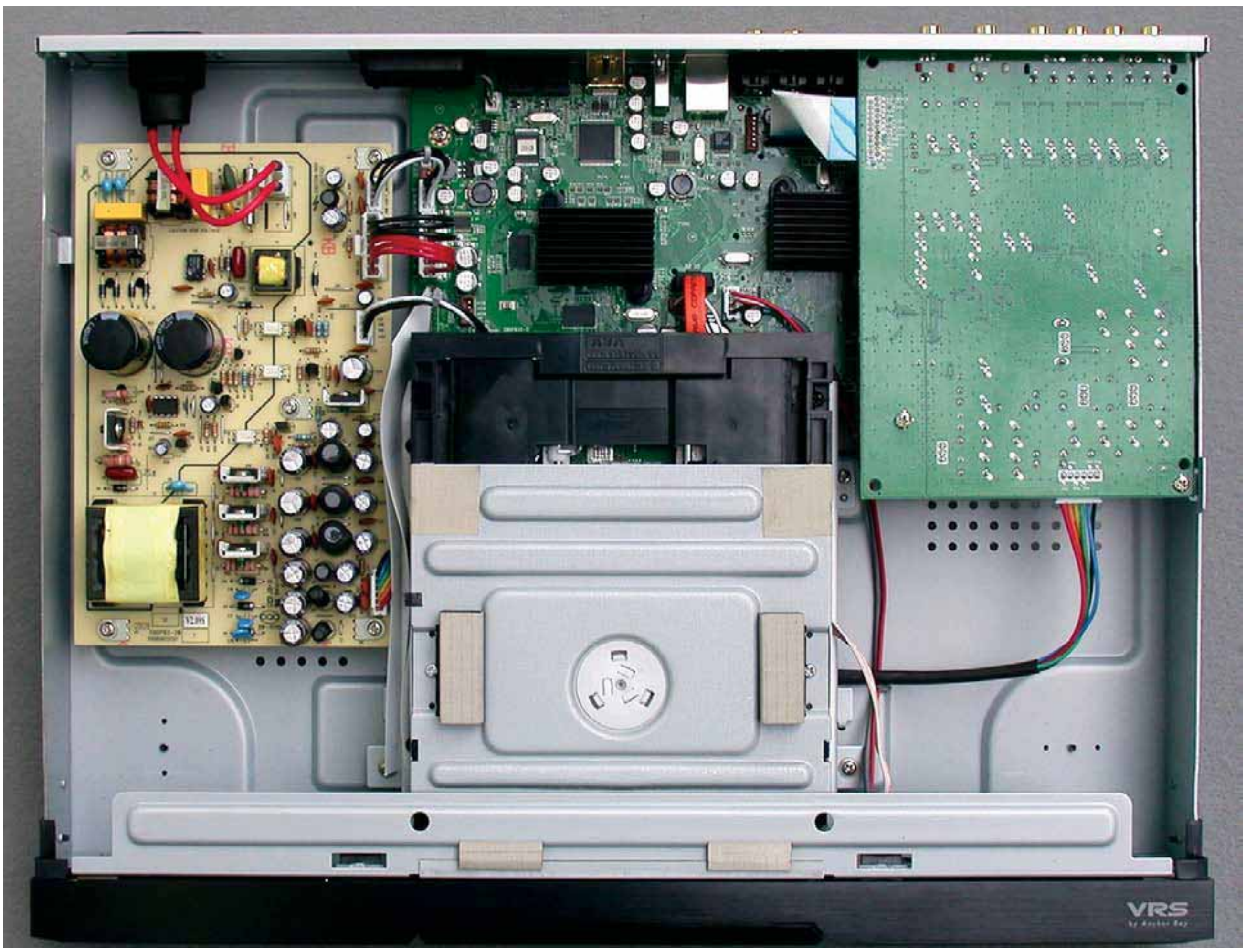


PHOTO 5: Inside view of the well-constructed Oppo Blu-ray player. The power supply board is on the left, the video board is in the center, and the analog board is mounted component-side down on the right, above the right half of the video board.

5532. The outputs of each 5532 amplifier are capacitor-coupled to the player's output jacks.

The two-channel stereo voltage outputs of the CS4398 are also fed to TI 5532 op amps, but each channel uses an entire 5532. Because the CS4398 does not have current outputs, the other half of the op amp can't be a current-to-voltage converter. And, since the outputs of the 5532s are still capacitor-coupled, you can be reasonably sure that it's not a DC-servo integrator. Both the CS4382A and CS4398 DACs have true differential outputs, which are probably fed to the inverting and non-inverting inputs of a single 5532 half for each of the 7.1 channel outputs (this is the configuration suggested in the CS4382A and CS4398 data sheets). For the two-channel stereo signal path, Oppo may have opted to use a separate amplifier for the inverting and non-inverting DAC outputs, summing the outputs of each half of the 5532, but without a schematic this is only speculation.

For the two-channel stereo outputs, Oppo has bypassed the electrolytic coupling capacitors with polystyrene caps. I applaud the extra effort Oppo has put into the stereo outputs—this is especially important to those of us who have no interest in surround. I do wish that Oppo had used something better than the 5532 for the stereo outputs, but I understand that cost was undoubtedly a factor. The stereo signal path also has a footprint on the PC board for coupling capacitors between the DAC chip and the output op amps, but this feature is not used in current production. If low-offset op amps were substituted for the 5532s, high-quality film capacitors could be used in these locations, eliminating the need for the electrolytic output coupling capacitors (the input impedance of the op amp stage following a DAC is usually high enough to allow this).

Based on past experience, I would expect the replacement of the 5532s and elimination of the electrolytic coupling caps would make significant improvement in the sound of the stereo outputs. There is one discrete, surface-mount transistor associated with

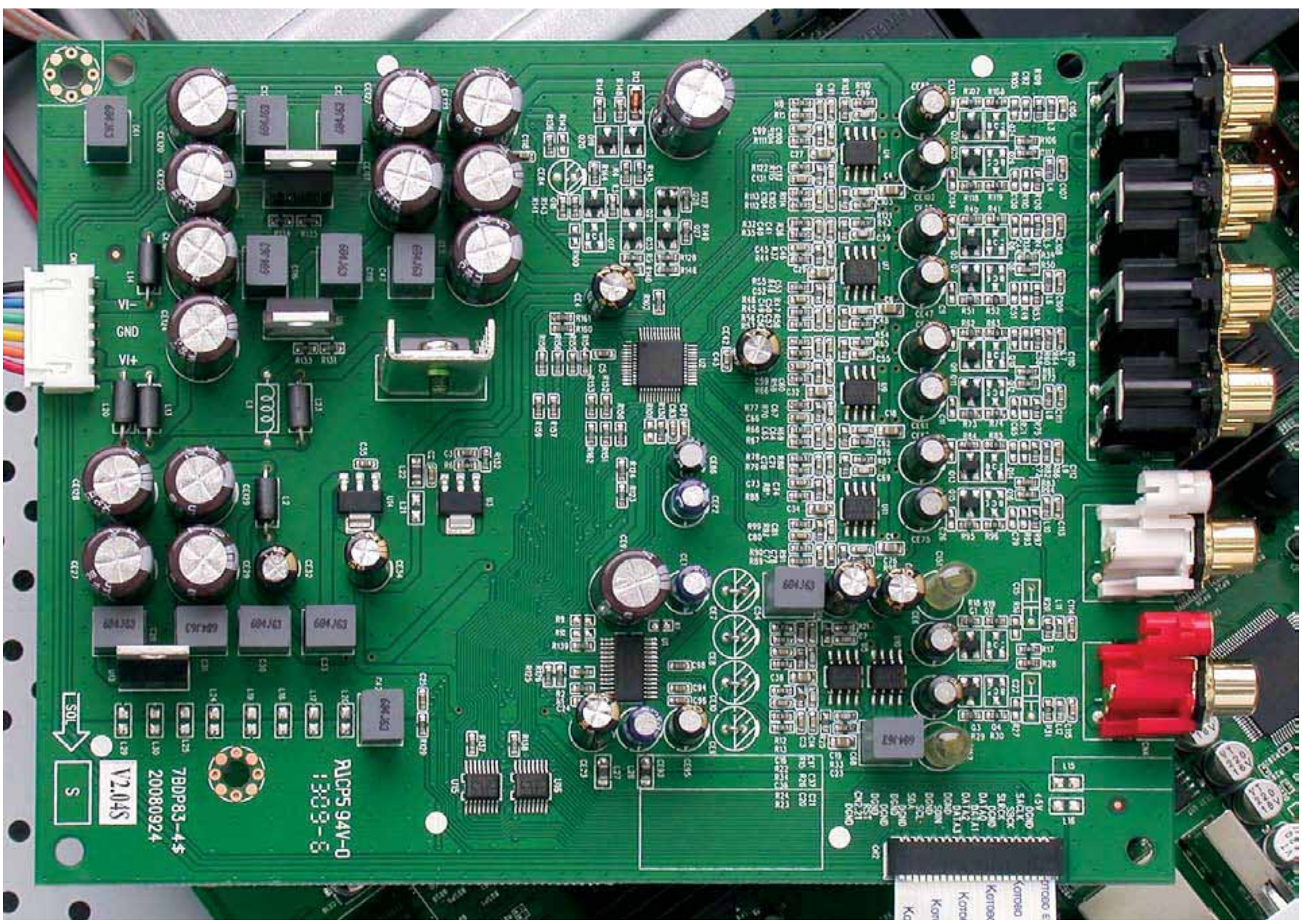


PHOTO 6: Close-up of the analog circuit board. The Oppo player uses separate Cirrus Logic DAC chips for the multi-channel and two-channel stereo outputs. The analog circuitry is based on Texas Instruments 5532A op amps, which are capacitor-coupled to the output jacks.

each of the ten analog outputs, which is probably for output muting. The PC board also contains footprint for one more surface-mount transistor per channel, but that footprint is unused.

Like nearly all Blu-ray, DVD, and multi-format players, the BDP-83 has a switching power supply. This has the advantage of making the unit truly universal—with the appropriate power cord, it can be used in any country without rewiring or changing transformers. Supply regulators on the analog/DAC board include two 7805 regulators for the digital rails, plus one LM317 and one LM337 for the analog supplies.

All electrolytic capacitors at the regulator inputs and outputs are bypassed with 0.68µF polyester film caps. Local bypassing for the 7.1-channel analog circuitry consists of small, surface-mount "chip" type capacitors. But the dedicated stereo outputs have their own 220µF electrolytics bypassed with 0.68µF polyester films, another welcome choice.

VIDEO PROCESSING

The video circuitry in the BDP-83 is based on Anchor Bay's ABT2010 VRS (Video Reference Series) technology IC, a chip normally found in much more expensive players (**Photo 7**; www.anchorbaytech.com). According to the description on the Anchor Bay website: "The ABT2010 is Anchor Bay's second-generation video processing chip ideally suited for deinterlacing and format conversion applications in digital displays, DVD, HD-DVD, Blu-Ray player/recorders, and AV receivers. The chip features all of the processing power of Anchor Bay's Video Reference Series™ (VRST) technologies, including Anchor Bay's proprietary Precision Deinterlacing™ that provides five-field motion adaptive and edge adaptive processing for an artifact-free viewing experience."

Anchor Bay further notes that the ABT2010 incorporates their 10-bit Precision Video Scaling II™ system that independently scales an image horizontally and vertically to achieve the finest possible picture definition from HDTVs. The chip also has their Progressive Re-Processing (PReP™) technology, which Anchor Bay describes as "a breakthrough processing method that reverts the progressive video signal output from source equipment to its original interlaced format, and then converts the interlaced signal to progressive format using Precision Deinterlacing." The ABT2010 is fully compatible with the HDMI 1.3 standard. Oppo also uses their own OP8521G video decoder chip which, according to several internet sources, is a slightly modified Mediatek MT8520 (http://www.avsforum.com/avs-vb/showthread.php?t=1124287&page=268, http://www.avbuzz.com/bbs/av/

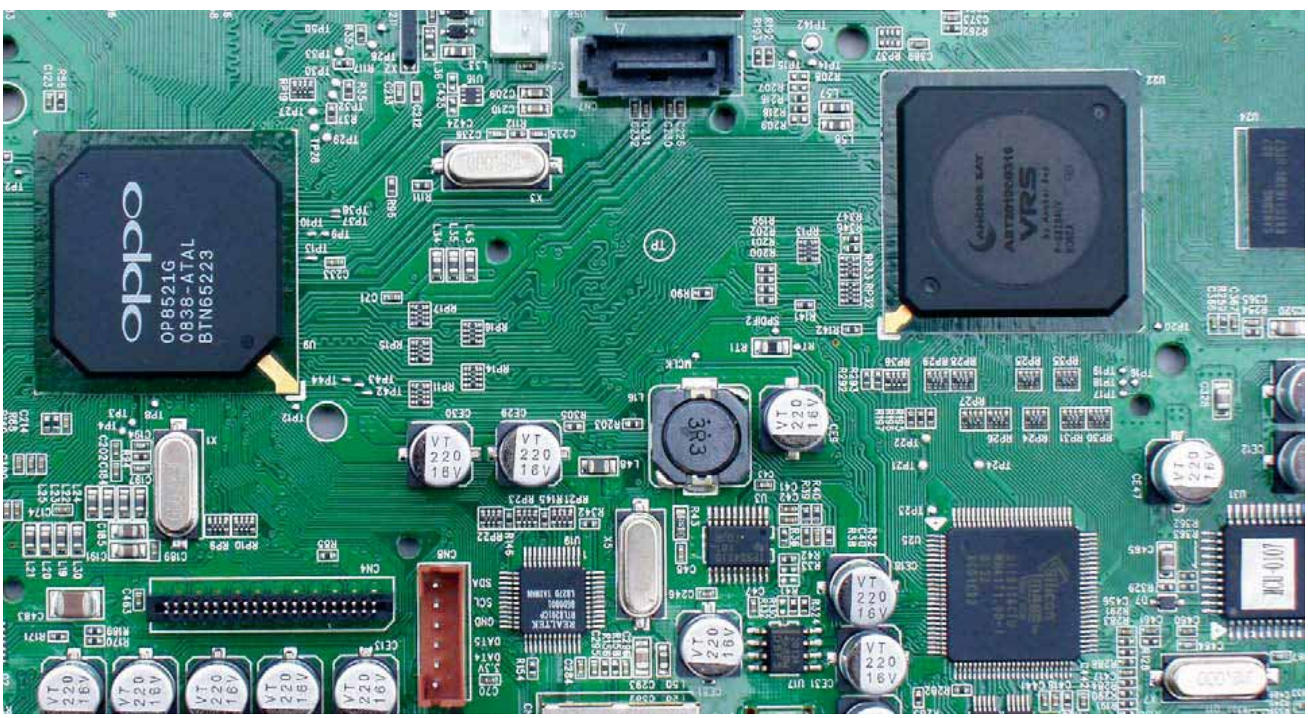


PHOTO 7: Close-up of the BDP-83 video board. The Anchor Bay ABT2010 Video Reference Series video processor is shown in the upper right, and Oppo's own OP8521G video decoder is in the upper left. Both chips are normally hidden by substantial heatsinks (courtesy of Oppo Digital).

av-thread-110908-25-asc.html).

SYSTEM SETUP

The Oppo BDP-83 has an intelligent and generally well-written owner's manual that is clear and to the point. However, the manual supplied with your player may be dated, so I strongly suggest downloading the latest version from their website. My manual listed DVD-Audio discs among the "Discs that cannot be played," which is clearly not the case—the BDP-83 has full support for the DVD-Audio format. The downloadable manual has been corrected. Altogether, Oppo has added four additional pages to the downloadable manual.

After you download the latest manual, it's important to check the firmware to make certain that you have the latest version. The firmware version in the player can be identified by going to Device Setup in the setup menu. The Oppo website has information on the latest version, which you can download and burn to a CD as an image (most free CD burning programs that come bundled with computers will allow you to do this). Then you can insert this CD into the Oppo player for installation—complete instructions are provided on the Oppo website. If your player is connected to a computer network, you can upgrade the firmware directly, online.

After I updated my firmware, a very strange thing happened: Audio on CDs sounded as though it was being followed by an echo. The music sounded as though it was out-of-sync with itself, as if the orchestra was not together. Oppo's Jason Liao suggested going into the setup menu and selecting "Device Setup—Reset Factory Default," redoing any custom settings that I needed, and then turning the power off. But, after turning the player back on, the problem persisted. At that point, I powered my system down and called it an evening.

I should point out that my low-level equipment is powered by a PS Audio Power Plant Premier (www.audioamateurinc.com). When the Power Plant Premier is turned off, power is disconnected to all equipment, just like pulling the plug. The next morning I powered up the system, and found that everything worked properly. I then realized that my television speaker had been on the entire time I was doing the firmware upgrade, because the TV screen displays necessary, interactive information when you perform this upgrade. So, I turned the TV on, but the echo problem did not return.

Here's my theory, for whatever it's worth: After performing the firmware upgrade, the sound coming out of the TV speakers was out of sync with the sound from the player's stereo analog outputs. A reset followed by a complete shutdown, including disconnecting power, was necessary in order to correct the problem. I have since turned off the TV speaker permanently in the setup menu. Many DVD-Audio discs require a TV display in order to select the stereo or multi-channel program, and then to select tracks. You certainly don't want your TV speakers on when you're listening to music! This problem has not reappeared since the initial firmware upgrade.

Chuck Hansen and I both observed another glitch in the operation of the BDP-83. [Chuck's audio measurements of the BDP-83 will follow next month.—Eds.] On a couple of occasions the player refused to eject a disc. When this happened, even unplugging the unit for a minute and plugging it back in did not cure the problem. When the player was powered back up and turned on, the opening HELLO message remained frozen on the display (when the player is working properly, the player should either recognize the disc or display a NO DISC message after a few seconds). We both found that the player worked fine when we powered it back up the next day. Oppo's Jason Liao concluded, as we did, that our sample had some sort of intermittent problem, so he promptly sent us another player.

I have not experienced this problem with the replacement, but I did have one other one-time glitch. While playing the beginning of one of the original *Star Trek* episodes, I heard some audio crackling for a short time, and the "Ø" symbol displayed in the upper-left-hand corner of the screen (this is the symbol you get when you try to execute a function the player will not permit, such as moving to the top menu during the FBI warning). After a power down, the problem disappeared.

These glitches in the first and second players occurred after I tried to eject a disc using the button on the front panel, rather than the remote. It's possible that the player is sensitive to static electricity, though I was not aware of any static discharge when I touched the front panel. Fortunately, these seem to be random occurrences always righted by disconnecting power and starting over. Oppo has shown a high commitment to customer support, so I have reasonable confidence that these problems will be worked out.

VIDEO PERFORMANCE

I viewed the Oppo BDP-83 on my 42″ Panasonic TH-42PZ85U plasma television (I'm still not a big fan of LCD TVs, though they have improved considerably). This TV is certainly not the largest one available, but properly set up, it has an absolutely stunning picture and is certainly capable of revealing subtle differences in the quality of source material.

My normal Blu-ray player is a Marantz BD7003, which I purchased in January 2009. This player, with a list price of $549, also plays video DVDs and audio CDs. It does not play SACD or DVD-Audio and therefore is not a multi-format player. I have found the Marantz to be a superb performer with outstanding picture quality and glitch-free performance.

One of the problems with the Marantz and many other players is slow Blu-ray disc access. It can take the Marantz 30 seconds or more to recognize a Blu-ray disc from the time the disc is inserted in the player. The Oppo will usually begin playing a Blu-ray disc in about half that time, and is even faster on many discs.

I ran across one peculiarity on the Blu-ray edition of the very first James Bond movie. When I insert *Dr. No* into the Oppo player, the player seems to mute the HDMI video output as it navigates from one screen to the next, and each time a new screen appears—opening black screen, FBI warning, and then the top menu—my television displays the selected video input in the upper-left corner of the screen. When it arrives at the top menu, the first note of the Bond theme music is missing—the top menu begins on the second note. The Marantz navigates smoothly through these screens and starts the top menu at the beginning of the theme music.

Jason Liao offered the following explanation: "The HDMI re-sync at the beginning of the Dr. No movie is normal for BDP-83. Since the BDP-83 uses an external video processor (ABT2010), any resolution change of the source material will cause the HDMI to re-sync. The FBI warning screen could be encoded in 1080i format while the main menu and film are likely 1080p24Hz. The Marantz 7003 is likely a single chip solution without an external video processor so it can avoid the re-sync." The BDP-83 has no problem playing the movie, however, and I don't consider this to be a serious issue.

The BDP-83 is supplied with the *Spears & Munsil High Definition Benchmark Blu-ray Edition*, which contains some very impressive high-def demonstration material plus a complete battery of tests for Blu-ray players and HDTVs. The demonstration "Montage," as it's titled, consists of outdoor video shot in Washington and Oregon using a Red One digital camera (www.red.com) at a resolution of 4096 × 2048, which is a 2:1 aspect ratio (on a 16 × 9 HDTV small black bars appear on the top and bottom of the image). Editing was done on a MacBook Pro running Final Cut Pro. Spears and Munsil used their own proprietary software to downsample the TIFFs to 8-bit 4:2:0 at 1920 × 1080 (my thanks to Stacey Spears at Spears and Munsil for providing details on how the "Montage" was made).

I ran the Blu-ray tests on the Marantz and the Oppo players and, in most cases, it was difficult to distinguish between them, with both players negotiating most of the tests without difficulty. However, the Oppo was clearly superior to the Marantz on the Source Adaptive Deinterlacing Clips. On the 2-2 wedge pattern, as an example, the Marantz exhibited moiré over the entire horizontal wedge and most of the vertical wedge. On the 2-2 racecar clip, moiré pattern was visible on the bleachers through most of the clip.

The Oppo displayed moiré on only the last quarter of the horizontal wedge pattern, near the tip, which is as it should be, and on only half of the vertical pattern. Similarly, the moiré pattern in the bleachers was visible only at the beginning of the clip, disappearing afterwards. The Marantz also fell short on the Edge Adaptive Deinterlacing Clips, showing some jaggies on the test pattern and on the Brooklyn Bridge. The Oppo was not flawless, but performed noticeably better on these tests than the Marantz.

On Spears and Munsil's high-def "Montage" both players delivered stunning picture quality. The same was true of the Blu-ray editions of *Dr. No* and *Star Trek—The Original Series, Season 1*. The fact that the multi-format Oppo can hold its own with a comparably priced player that does not support high-res audio formats is very impressive. The Oppo also does a superb job up-converting conventional DVDs to 1080p. Compared to my Marantz, the Oppo has more vivid colors and less noise. Although the Blu-ray transfers of *Never Say Never Again* and *Blazing Saddles* are sharper than the DVD versions, the DVDs are nonetheless extremely good up-converted by the Oppo player.

THE SOUND

Like other multi-format players, the Oppo has a Pure Audio Mode that turns off the video processing circuitry and video outputs to prevent interference between the video and audio circuitry. My experience with other players is that this can make a subtle improvement in the sound, particularly in high-frequency smoothness and detail. When listening to audio discs, I normally activate the Pure Audio Mode.

The main audio player in my system is a NAD M55, a multi-format player that supports just about everything except Blu-ray. I normally use the M55 with my PS Audio Digital Link III D/A converter for all PCM material. For SACDs, I use the M55 as a stand-alone player. Although there are dedicated SACD players that probably offer superior sonic performance to the M55, as a multi-format player it is difficult to beat, especially for the asking price of $1799. I have no interest in surround sound, so my evaluations of the Oppo are based on stereo performance using its two-channel stereo outputs.

Throughout the month or so that I had the Oppo player for audition, I was continually impressed with how much Oppo has achieved, sonically, for the asking price. Although the first unit I received performed well, the second unit supplied by Oppo actually performed better than the first, and the comments that follow are based primarily on the second sample.

Tonal balance is quite neutral throughout the midrange, accented by a touch of brightness in the treble region. This is most noticeable on CDs that are tonally bright, such as the Mercury of Schoenberg's *Five Pieces for Orchestra*, and the Decca Originals CD transfer of Strauss's *Salome* conducted by Solti. I observed a similar brightness in the Benchmark DAC-1 USB, reviewed by Chuck Hansen and me in *aX* 1/09. The Benchmark also uses TI 5532 op amps, but with its almost nonexistent clock jitter and DC servo control of the analog op amps, it is certainly more transparent.

The low end is surprisingly deep, especially on the SACD transfers of the early Telarc material, or analog sources with real low end, such as

COMPANY PROFILE

Just who is Oppo, anyway? Most readers, like me, probably assumed that they were another Far-East company with manufacturing in China, selling their wares under the Oppo brand name in the United States. I was pleasantly surprised to learn that Oppo is actually a US-based company. Jason Liao, Chief Technology Officer and Vice President of Product Development, provided this brief history of the company:

"OPPO Digital has a relatively short history. The company was founded in 2004. The founders came from engineering and IT backgrounds in various Silicon Valley companies. All of us had an interest in home theater and worked in the fields of video compression, e-commerce, and hardware/software development. We started the business with the idea of making a good up-converting DVD player and selling it through e-commerce.

"The first product was OPDV971H with a DVI port and DCDi by Faroudja video processing, and it was released in early 2005. Because of our direct-to-consumer e-commerce sales channel, we can get feedback from customers and implement feature updates in firmware/hardware very quickly. We found this very beneficial to both the company and our customers, and the customer-oriented approach of product development becomes a company culture. Over the years we built a few more universal up-converting players and gradually improved audio performance with each new model. The BDP-83 is our first Blu-ray Disc player. During the development of the player we did extensive private beta tests and two rounds of public "Early Adoption Program" to ensure that the player meets customers' expectations."

Oppo's website provides some additional insights into the company philosophy:

"Based in the heart of Silicon Valley, OPPO Digital designs and markets high quality digital electronics that deliver style, performance, innovation, and value to A/V enthusiasts and savvy consumers alike. The company's attention to core product performance and strong customer focus distinguishes it from traditional consumer-electronics brands. With products that speak for themselves and relying on word-of-mouth, OPPO Digital does not have any dedicated Marketing and Sales personnel. We have spent most of all energy on product design and customer service."

Oppo has an "Early Adoption Program" with a network of users that purchase and field-test pre-production products—Oppo's website gives feedback they receive on each product during two rounds of testing and upgrades. This ensures that products really are ready for prime time when they are finally sold to the public. Oppo's commitment to value and customer support can be seen in the prices they charge for accessories. HDMI cables are very reasonably priced, with a 15¢ cable selling for $29. Remote controls sometimes become broken or lost, and some manufacturers are known to charge $50 to $100 for replacements. Oppo gets a refreshing $9.50 for a replacement remote for the BDP-83.

Oppo's corporate philosophy is an admirable one and the track record of their products thus far indicates real leadership in the A/V field when it comes to value and customer support. Oppo does not have retail dealers, which allows them to keep prices low by eliminating the middle man. Their products can be purchased online at the company website, or from a number of Internet dealers including amazon.com. ■

TABLE 1: Reference Recordings

CDs
- Dukas: *The Sorcerer's Apprentice*. Boston Symphony Orchestra conducted by Charles Munch. RCA Victor Living Stereo 68978-2.
- Ravel: *Alborada del Gracioso*. L'Orchestre de la Suisse Romande conducted by Ernest Ansermet. London 433 717-2.
- Rimsky-Korsakov: *Scheherezade*, Op. 35. Chicago Symphony Orchestra conducted by Fritz Reiner. RCA Victor Living Stereo 68568-2 (UV22-Encoded Limited Edition Gold CD version of 68168-2).
- Mussorgsky/Ravel: *Pictures at an Exhibition*, especially track 2, "Gnomus". Chicago Symphony Orchestra conducted by Fritz Reiner. RCA Victor Living Stereo 68571-1 (UV22-Encoded Limited Edition Gold CD version of 61958-2).
- Schoenberg: *Five Pieces for Orchestra*, Op. 16. London Symphony Orchestra conducted by Antal Dorati. Mercury Living Presence 432 006-2.
- Respighi: *The Birds*. London Symphony Orchestra conducted by Antal Dorati. Mercury 432 007-2.
- Wagner: *Der Ring des Nibelungen*, especially "Siegfried's Death and Funeral March" from *Götterdämmerung* (CD 4, Tr. 10-11), and the "Forging Scene" from Siegfried (CD 2, Tr. 3-5). Birgit Nilsson, Wolfgang Windgassen, et al. Vienna Philharmonic Orchestra conducted by Georg Solti. Decca 455 555-2.
- Strauss: *Salome*, especially "Wird dir nicht bange..." through Jokanaan's descent into the cistern, CD 1, Tr. 9. Birgit Nilsson, Eberhard Wächter, et al. Vienna Philharmonic Orchestra conducted by George Solti. Decca 475 7528.

SACDs
- *The Power of the Orchestra*. Mussorgsky, arr. Leibowitz: *A Night on Bald Mountain*; Mussorgsky, arr. Ravel/Leibowitz: *Pictures at an Exhibition*. Analogue Productions CAPC 2659 SA.
- Holst: First Suite in E-flat, Op. 28 No. 1. Cleveland Symphonic Winds conducted by Frederick Fennell. Telarc SACD-60639 (DSD transfer of 1978 Soundstream digital recording).
- Stravinsky: *Le Sacre du Printemps*. Cleveland Orchestra conducted by Lorin Maazel. Telarc SACD-60563 (DSD transfer of 1980 Soundstream digital recording).
- Mussorgsky/Ravel: *Pictures at an Exhibition*, especially track 2, "Gnomus". Chicago Symphony Orchestra conducted by Fritz Reiner. RCA Victor Living Stereo 82876-61394-2.
- Bartók: *Concerto for Orchestra*. Chicago Symphony Orchestra conducted by Fritz Reiner. RCA Victor Living Stereo 82876-61390-2.
- Stravinsky: *The Firebird*. London Symphony Orchestra conducted by Antal Dorati. Mercury 470 643-2

Audio DVDs
- Rachmaninoff: *Symphonic Dances*, Op. 45. Dallas Symphony Orchestra conducted by Donald Johanos. Classic Records DAD 1004. (96kHz, 24-bit PCM transfer of 30-ips analog tape, or possibly a 15-ips copy, engineered by David Hancock).
- Wagner: *Die Walküre*—Wotan's Farewell and Magic Fire Music. Houston Symphony Orchestra conducted by Leopold Stokowski. Classic Records HDAD 2029. (192kHz/24-bit DVD-Audio transfer of original Everest 35mm 3-track tape).
- Scriabin: *The Poem of Ecstasy*. Houston Symphony Orchestra conducted by Leopold Stokowski. Classic Records HDAD 2026. (192kHz/24-bit DVD-Audio transfer of original Everest 35mm 3-track tape).

Video DVDs
- *Never Say Never Again*. MGM 27616-85398.
- *Blazing Saddles*. Warner 18959.

Blu-Ray Discs
- *Spears & Munsil High-Definition Benchmark—Blu-ray Edition*. Spears & Munsil 98072-00201. www.spearsandmunsil.com
- *Star Trek—The Original Series, Season 1*. Paramount 14241.
- *James Bond Blu-ray, Volume One* (especially Dr. No). MGM 83904-12095.
- *Never Say Never Again*. MGM 83904 13727.
- *Blazing Saddles*. Warner 82838.

the *Reiner Pictures at an Exhibition*, Analog Productions SACD of *The Power of the Orchestra*, or Classic Records DVD of Rachmaninoff's *Symphonic Dances*. My NAD gives a bit more of the "feel" aspect of the bottom octave than the Oppo, and superior control of the low end, but the Oppo is very respectable.

The BDP-83 recreates a wide and quite precise lateral soundstage. Where it falls a bit short is in depth, which is rather shallow compared to a reference quality player. On recordings with excellent depth perspective, such as the Mercury Schoenberg *Five Pieces for Orchestra*, or the Analog Productions SACD *The Power of the Orchestra*, the back rows of the orchestra are moved forward so it becomes a bit difficult to gauge the distance of those players in the middle versus those in the very back. You need to use your imagination a bit to pinpoint front-to-back localization, though ambience in the rear of the stage is captured very well.

Inner detail in the midrange is very good. On really fine SACD material, such as the Mercury *Firebird*, it can be strikingly good. Where the player falls a bit short is in the treble region, where it can become somewhat congested on densely scored orchestral material. The Oppo doesn't match the clarity, detail, and smoothness in the treble that I've come to expect from the NAD M55. Dynamics are very impressive, especially on totally uncompressed material, such as the SACD transfers of the early Telarc digital recordings. Orchestral contrasts are realistically rendered. The main limitations here are the somewhat decreased heft in the extreme low bass and the congestion in the treble in fully scored passages.

The BDP-83 actually negotiated two DVD-Audio discs that have consistently given my NAD M55 trouble. These are the two Classic Records reissues of Stokowski/Houston Symphony recordings from 35mm Everest masters. In the Scriabin *Poem of Ecstasy* the 192kHz DVD-Audio program mutes at 12:40 on the M55, and then stops altogether. The 96kHz version of "Wotan's Farewell" from Wagner's *Die Walküre* does the same thing at 3:20. The Oppo BDP-83 has no trouble with these discs.

Early universal players were often criticized for uneven performance from one format to the next. Some offered good performance on DVD and SACD sources, but fell short on conventional Red Book CDs. Others performed well with PCM material, but SACD performance was lacking. The Oppo BDP-83, like my NAD M55, is a very well-balanced player, performing equally well on DVD-Audio, SACD, and Red Book CD material, with the quality of the sound dictated by the source. This consistency from one format to the next has become more common in multi-format players and can really be attributed to the improvements in the DAC chips that are now available.

High-performance players often use digital hardware from one of three companies—Cirrus Logic, Burr-Brown/TI, and Analog Devices—and the best chips from all three show that it's possible to do PCM and DSD decoding equally well with current technology. There have been many inexpensive players that failed to make a convincing case for DVD-Audio and SACD. The Oppo is good enough to reveal the superiority of well-produced high resolution discs over conventional CDs.

I also tried the Oppo as a transport, feeding its S/PDIF coax output to my PS Audio Digital Link III. The Oppo performs very well as a transport, but lacks the pristine detail and silky smoothness that I'm used to with the NAD. The tonal balance with the NAD is a bit darker, with a gutsier sonic presentation. Aside from the NAD, however, the Oppo surpassed any of the other players I've used as transports, including my old Onkyo DV-SP800 universal DVD player (which the NAD replaced).

CONCLUSIONS

The BDP-83SE sells for $899, and upgrades to existing BDP-83 players are available for $299. Performance via the digital outputs is unchanged, and Oppo recommends the regular BDP-83 if you intend to use an outboard digital audio processor. If you're looking for an affordable universal Blu-ray player, the Oppo is a welcome addition to the market. *rr*

Signal Current Loops and Power Supply Interaction

Sometimes, solid-state can bring out the best in tube sound.

The phrase "the sound of the rectifier" is always an alert to me. I assert that if the rectifier is audible, then there is signal current flowing in the least linear part of the circuit, the power supply, and, in particular, the rectifier! I have been on an explorative and experimental path looking to minimize the degree to which signal currents flow in the power supply. The first place to look is the output stage because the current requirements of that stage are the most demanding (usually).

In considering the output stage, the first issue to address is the class of operation. In this case, Class A has an advantage, so this article limits discussion to Class A operation. However, simply limiting designs to Class A is not enough. The problem is that the current demands of even a Class A stage will change according to the signal level.

For example, consider the datasheet case of a 45 triode operating single-ended in Class A at 250V with a bias current of 34mA, delivering 1.6W into 3.9kΩ. Placing a 3.9kΩ load line on the curves passing through 250V at 34mA, you can note that the plate currents at the ends of the line as defined by a grid swing of ±49.5V are at 67.5mA and 6mA, the mean of which is 36.75mA.

You can see that this is elevated 2.75mA compared to the quiescent current of 34mA. This is due to the departure of the tube from perfect linearity and is sometimes referred to as rectification; that is, the current in one direction is greater than the current in the opposite direction; a diode simply takes this difference in "back-to-front" current to the limit. When reproducing music, you rarely, if ever, encounter steady-state conditions (except for silence) and so this example is somewhat unrealistic; however, it does serve to illustrate that even in Class A, the signal will place demands on the power supply. So, given that no amplifying device is perfectly linear, what can you do to minimize audible sonic interaction of the signal with the power supply?

The traditional approach is to use a combination of chokes and capacitors acting as an energy reservoir to time-average the current demands resulting from the signal acting upon a less than perfectly linear output tube. That experimenters and observers often note "the sound of the rectifier" indicates that such traditional measures are not adequate in the quest for sonic fidelity. This article shows how you can isolate the signal from the power supply using a simple and practical technique.

SIGNAL CURRENT LOOPS

First, referring to **Fig. 1**, I'll review the signal current loops in a cathode-biased, single-ended output stage. The

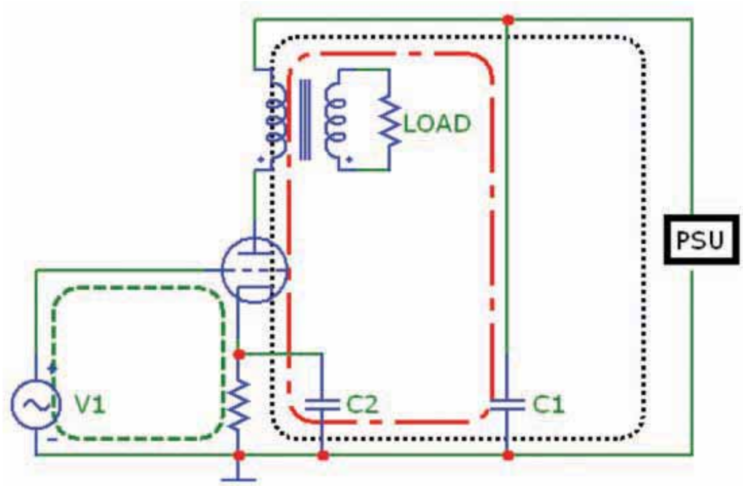


FIGURE 1: Single-ended signal loops.

first loop is the input loop (dashed). What is not commonly stated is that an amplifying device responds to a voltage *difference*; in this case, the difference between the grid voltage and the cathode voltage. If the grid voltage falls relative to the cathode voltage, the current passed by the tube falls and vice versa.

With a common cathode stage, the cathode is held at signal ground potential by the cathode bypass capacitor while the grid "sees" the input signal. The tube grid input impedance is not infinite; in fact, according to the *Radio Designer's Handbook* (4th edition): "When a valve is used at low audio frequencies, it is sometimes assumed that the grid input impedance is infinite. In most cases, however, this assumption leads to serious error, and careful attention is desirable to both its static and dynamic impedances."

For the purpose of this discussion, the serious error referred to is that the input signal has no current associated with it such that the input loop is usually not considered carefully. The point being that if a cathode bypass capacitor is used, this current flows from the source to the grid, to the cathode and via the cathode bypass capacitor back to the source and vice versa, alternating with the signal. *The cathode bypass capacitor is in the input signal path*.

The second case is the output loop (chain dashed). Similar to the input case, the output voltage develops across two terminals of the amplifying device, in this case the plate and the cathode. In the case of a transformer-coupled load, the voltage acting across the load reflected to the primary causes current to flow from the plate to the output transformer primary, to the PSU bypass capacitor to ground and via the cathode bypass capacitor to the cathode and vice versa, alternating with the signal current. Note that there are two capacitors in series wth the output signal current! (I will address this issue later in this article.)

The third case is the power supply (PSU) loop (dotted). In the case of a perfect Class A amplifier, there would be no power supply signal loop; the power supply would merely be feeding the circuit with energy to balance the energy dissipated in the load. Furthermore, if the PSU bypass capacitor were perfect (zero impedance at all frequencies), then the power supply would not be in the signal path.

However, there is no such thing as a perfect Class A amplifier or a perfect capacitor, so the power supply is in the signal path. To make matters worse, the energy supplied by both the power supply and PSU bypass capacitor must pass via the cathode bypass capacitor.

I have identified two signal path issues that audibly impact the sonic results of the circuit

1. Signal current flowing in the power supply
2. The cathode bypass capacitor that appears in all three loops: the input loop, the output loop, and the power supply loop.

Taking the power supply first, the traditional approach is to simply increase the energy storage, thereby increasing or stretching the period of the time-averaging of the signal flowing in the power supply. The obvious issue here is that the equivalent series resistance (ESR) of a capacitor is not flat with respect to frequency, and, even more, the impedance of the power supply as a whole is far from flat with respect to frequency. This means that the impedance of the power supply signal path is not flat and so the power delivered into the load is not flat with respect to frequency.

Note: Even if the measured performance appears flat, our ears are quite capable of distinguishing micro-effects that limit the potential musical beauty of an amplifier, and that is, I assert, the point of this hobby as long as we are having fun. Worse still, many L-C or C-L-C power supplies exhibit a severe resonance (impedance peak) in the region of 5 to 15Hz. In fact, all power supplies are to some degree reactive (i.e., they resonate), and this has a disastrous impact on the sonic results that some people may actually like; however, it is not conducive to fidelity.

When I started designing tube amplifiers (around 12 years ago), I was aware of the power supply resonance issue, and my approach was to employ tube-based voltage-regulated power supplies, which are quite effective.

The advantage of a regulator is that there is a substantial voltage drop across it that corresponds to available stored energy, greatly lessening the audibility of signal current flowing in the rectifier by increasing the time-averaging effect. I then started using a simple MOSFET series regulator with a reference voltage on the gate. (I also put a long RC time-constant on the gate to obtain slow turn-on.) This is highly effective, affording notably flat power source impedance in the 6Ω region. I noticed that the sound improved over that of relatively sophisticated error compensating tube power supplies.

POWER SUPPLY PROBLEM

However, I believed I could do better. The problem is that the power supply signal loop is now a composite of the regulator and the bypass capacitor. The tube regulators I built have source impedances in the 1 to 4Ω region. This means that up to 1000Hz or so[1], I was listening to the regulator, while above 1000Hz the PSU bypass capacitor dominated the sonic results. "Listening to the regulator" is a common and valid objection to voltage-regulated power supplies. The series MOSFET may improve the sonics of the regulator by eliminating the error amplifier.

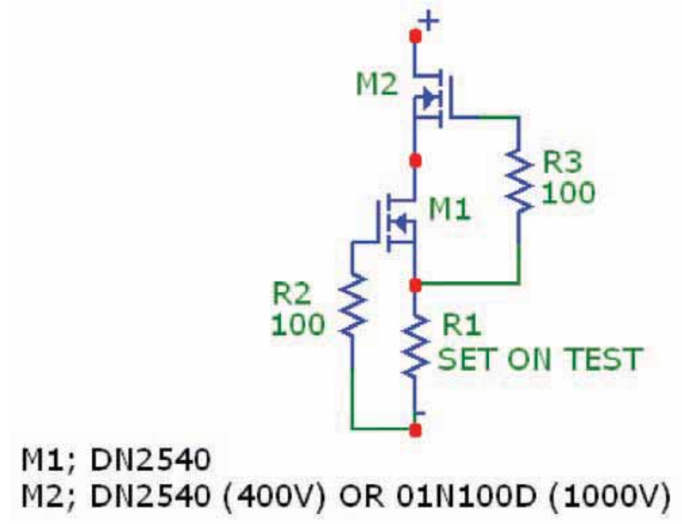


FIGURE 2: Depletion mode cascode MOSFET two-terminal constant-current regulator.

Even so, you are still left with the problem of the rectification effect of the amplifier tube causing current demands that are not adequately managed by the power supply in sonic terms.

Many of you may find the use of solid-state devices bothersome for various reasons. I assert that there are a few ways in which solid-state devices free us to explore topologies that, while not necessarily new, are not practical when using tubes only. In fact, used with due attention to detail, there is a particular solid-state device that *permits fuller realization of the inherent sonic beauty of vacuum tubes*; The solution to the power supply signal interaction problem that I am proposing is to harness depletion mode MOSFET technology to produce truly effective isolation of the signal from the power supply.

I did a simple investigation of the performance of the two-terminal depletion mode MOSFET cascode CCR (**Fig. 2**). Note that I use the initials CCR—viz., constant-current regulator, because this device is equally effective as a source or a sink.

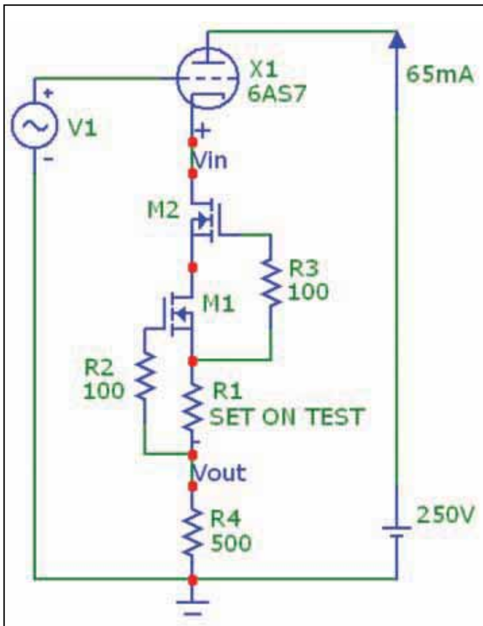
I found that using the Supertex DN2540 for M1 and M2, the measured DC current variation was less than 0.5mA over a range of impressed DC voltage from 50V to 200V, and the variation was immeasurable over a 100V range. This is extraordinary performance for such a simple two-terminal circuit.

Some users report that for plate or cathode "load" applications, the IXYS 01N100D is superior sonically. I have not attempted such a comparison; I did repeat the DC current test using the 01N100D for M1 and M2, and the performance was not acceptable. I then replaced M1 with the DN2540 and found the resulting DC performance to be acceptable but not quite as solid as that obtainable when using the DN2540 for both M1 and M2.

The AC test setup used one section of a 6AS7 as a cathode follower, with the CCR (using the DN2540 for both M1 and M2) in the cathode circuit (**Fig. 3**). I inserted a test load of 500Ω between the CCR and the negative rail and drove the 6AS7 such that 20V RMS (Vin) was measured at the cathode and then measured the voltage (Vout) at the load. I ensured that Vin was constant for each test frequency. The AC impedance of the CCR is very sensitive to the value of the gate stopper resistor; I chose to implement the design using the same value chosen by Walt Jung, 100Ω2. (It is worth noting that I have not experienced oscillation of the CCR devices I have built using 100Ω gate stopper resistors.)

My results are very different from those of Walt Jung, probably due to a different test method and much higher current combined with a large impressed DC voltage and large signal voltage. However, my setup represented my application. At a test current of 65mA, the cascode CCR exhibited an impedance greater than 1.5MΩ over a range of 10Hz to 40kHz.

This circuit is quite remarkable and opens the door to new, extreme-performance tube audio implementations that were not possible before the advent of depletion mode power MOSFETs. My preferred choice of devices is



V1; INPUT VARIED 10Hz TO 100kHz
M1; DN2540
M2; DN2540
R4; LOAD
Vin; HELD CONSTANT AT 20Vrms
Vout; MEASURED VARIABLE

Zccr = (500*Vin/Vout)-500
REJECTION = 20Log10(Vin/Vout)
OR; 20Log10(500/Zout)

F	Z Meg	REJECTION Db
10	1.72	71
100	2.08	72
1k	2.5	74
10k	2.56	74
20k	2.1	73
40k	1.58	70
100k	0.667	62

FIGURE 3: Constant-current regulator test setup and results.

the DN2540 for M1 and the 01N100D for M2. Note that the 01N100D is rated for 1000V, whereas the DN2540 is rated for 400V. Because the V_{DS} of M1 is limited by the V_{GS} of M2, the voltage withstanding capacity of the cascode CCR is determined by the voltage rating of M2.

REMOVING THE POWER SUPPLY SIGNAL LOOP

Given that a CCR has an impedance of 1.5MΩ or greater over and beyond the audio spectrum, placing a CCR in series with the plate supply will result in almost perfectly constant-current. That is, the power supply will not be modulated by the signal and will simply feed energy to the circuit to balance the energy dissipated in the load (**Fig. 4**). This is the ideal I am striving for. To justify this, take a look at some numbers: I will continue with the 45 triode operating single-ended in Class A at 250V with a bias current of 34mA having a plate resistance 1.75kΩ and a reflected load of 3.9kΩ.

You first must establish the resistance of the stage at the lowest frequency of interest, say 5Hz. You also have an output transformer with a primary inductance of 40H. The impedance at 5Hz is given by $2 \times \pi \times f \times L = 2 \times \pi \times 5 \times 40 = 1256\Omega$. In parallel with this you have the reflected load—with the 45 triode—of 3.9kΩ, resulting in a composite load of 1.256kW in parallel with 3.9kΩ = 0.95kΩ.

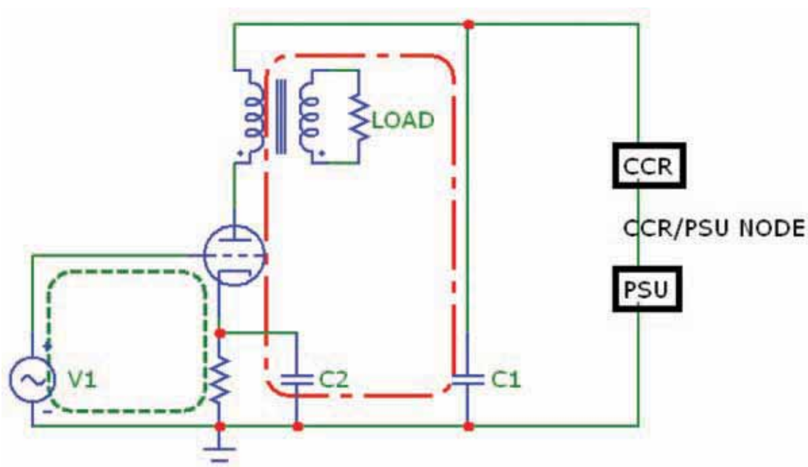
In series with this you have the plate resistance—again, for the 45—of 1.75kΩ, and the cathode bypass capacitor—say, for the purpose of discussion—of 2Ω, which is negligible, so ignore it. The resulting stage resistance is 0.95kΩ + 1.75kΩ = 2.7kΩ.

Let the plate signal current be I_P. If there were no PSU bypass capacitor, the voltage due to the signal at the PSU end of the output transformer would be $I_P \times 2.7k\Omega$ (neglecting the Thevenin effect of the CCR and PSU impedance because 1.5MΩ >>> 2.7kΩ). The PSU source impedance and the CCR impedance form a potential divider, the top leg being the CCR impedance and the bottom leg being the assumed PS source impedance of 2Ω.

For a potential divider, $V_{OUT} = V_{IN} \times R_{BOTTOM}/(R_{TOP} + R_{BOTTOM})$, and so the voltage at the CCR/PSU node is: $V_{CCR}/P_{SU} = IP \times 2.7e3 \times 2\ /(1.5e6 + 2)$, which simplifies to $I_P \times 3.6e^{-3}$. Now, to calculate the power supply rejection ratio, simply divide the voltage at the CCR/PSU node by the voltage at the PSU end of the output transformer giving: $PSRR = I_P \times 3.6e^{-3}/I_P \times 2.7e^3 = 1.333e^{-6}$, or -117.5dB, which is an excellent result!

Note: If you are following closely, you will have noticed that the stage resistance cancels and that the PSRR may also be calculated by dividing the PSU source impedance by the CCR impedance. If you are pedantic, you will include the PSU source resistance in the denominator, but 1.5MΩ >>>> 2Ω, so I will neglect it. This gives the power supply rejection ratio as $2/1.5e^6 = 1.333e^{-6}$, or -117.5dB, which is the same figure I calculated from first principles, and so you can see that the power supply rejection ratio is dominated by the impedance of the CCR. This analysis illustrates and confirms the effectiveness of CCR as a powerful tool in the quest to isolate the signal from the PSU.

In fact, 117dB is close to or beyond the dynamic range of hearing, so it is possible that I have achieved the ideal. *Any signal current modulation of the power supply will now be inaudible, and the power supply is now doing the only thing you need it to do; that is, supplying the energy dissipated by heating of the circuit elements and in the load.* Note: Even if the power supply impedance rises to 100W (quite possible if resonance is present), the power supply rejection ratio is dominated by the CCR and will still be -83dB



V1; INPUT SIGNAL
DASHED; INPUT SIGNAL LOOP
CHAIN DASHED; OUTPUT SIGNAL LOOP
C1; PSU BYPASS CAPACITOR
C2; CATHODE BYPASS CAPACITOR

FIGURE 4: Single-ended signal loops with CCR.

CAPACITOR CONCERNS

Now that you have effectively removed the power supply loop from the signal output loop, the output signal loop completion is simplified to the PSU bypass capacitor. What value should this capacitor be?

The signal output or load loop comprises the stage resistance (already calculated as 2.7kΩ), the PSU bypass capacitor to ground, and then via the cathode bypass capacitor to the cathode. (Note that the PSU capacitor and the cathode bypass capacitor appear in series, the consequences of which I examine later.)

The minimum value of the bypass capacitor is given by C = reciprocal ($2 \times \pi \times f \times R$). Again, your lowest frequency of interest is 5Hz and so you have reciprocal ($2 \times \pi \times 5 \times 2.7e^3$) = 11.78, rounded up to 12μF.

This value is available in high-quality film devices; you no longer need to horribly compromise your lovingly produced signal path with an electrolytic capacitor. I usually parallel this with an excellent coupling capacitor such as an Auricap of not more than 1/100 value. In this case, 0.1μF would be a good choice.

Now, take a look at the cathode bypass capacitor. To bias the 45 according to the example, the cathode bias resistor will be 50V/45mA = 1.11kΩ. Thevenin tells us that this resistance appears in parallel with the cathode resistance, given by 1/Gm. In your case, the datasheet gives Gm as 2.175mA/V; taking the reciprocal, you get the cathode resistance as 0.46kΩ, which in parallel with 1.11kΩ gives 0.325kΩ. Again, taking the lowest frequency of interest to be 5Hz, the value of the cathode bypass capacitor is reciprocal ($2 \times \pi \times 5 \times 325$) = 100μF.

As I have already noted, this capacitor appears in series with the PSU bypass capacitor, thus reducing the PSU bypass capacitance to reciprocal (1/12 + 1/100) = 10.7μF, which is not too bad. Increasing the PSU bypass capacitor to 13.6μF (say 15) will serve your design intentions. Please note, however, that the cathode bypass capacitor not only appears in the signal input loop but also in the signal output loop in series with the PSU bypass capacitor[2]. No capacitor has flat ESR with frequency, and the larger the capacitor, the worse the ESR behavior. Connecting two large capacitors in series makes matters worse. This is why I am a staunch advocate of grid bias[3] (or, in the case of voltage gain and drive stages, LED bias). The sonic impact of cathode bypass capacitors is far from theoretical; it is very audible.

The PSU bypass capacitor will increase the power supply rejection ratio because the instantaneous signal current will be sourced by the bypass capacitor. The effect of the capacitor is to drastically reduce the voltage due to the signal at the PSU end of the output transformer. This will now be given by the plate signal current multiplied by 2.7kΩ in parallel with the ESR of the capacitor, say 2Ω. To be pedantic, you should also consider the CCR resistance and the power supply source impedance that is 1.5MΩ + 2Ω.

Because 1.5MΩ is very much greater than the capacitor ESR of 2Ω, the effect is negligible, and so I will use 2Ω, giving the voltage at the PSU end of the output transformer as $I_P \times 2$. This can be compared with the previously obtained result of $I_P \times 2.7\text{k}\Omega$.

As before, the PSU source impedance and the CCR impedance form a potential divider, the top leg being the CCR and the bottom leg being the assumed PS source impedance of 2Ω. Again using the potential divider equation, the voltage at the CCR/PSU node will now be $(I_P \times 2) \times 2/(1.5e^6 + 2)$, which simplifies to $I_P \times 2.667^{-6}$. Again, to obtain the power supply rejection ratio: PSRR = $I_P \times 2.667^{-6}/I_P \times 2$ = 5.334^{-7} or -125.5dB.

SINGLE-ENDED IMPLEMENTATION

Figure 5A shows a parallel feed CCR topology that is a Western Electric concept I came across in Lynn Olson's presentation "Loop Distortion"[4]. In this case the CCR acts as a gyrator, while the output transformer is parallel-fed by a capacitor that closes the output loop directly to the cathode. The classical version of this circuit uses a choke in place of the CCR, providing a large degree of isolation from the PSU. This may be one reason why parallel feed amplifiers have a strong following. However, a choke may not provide the

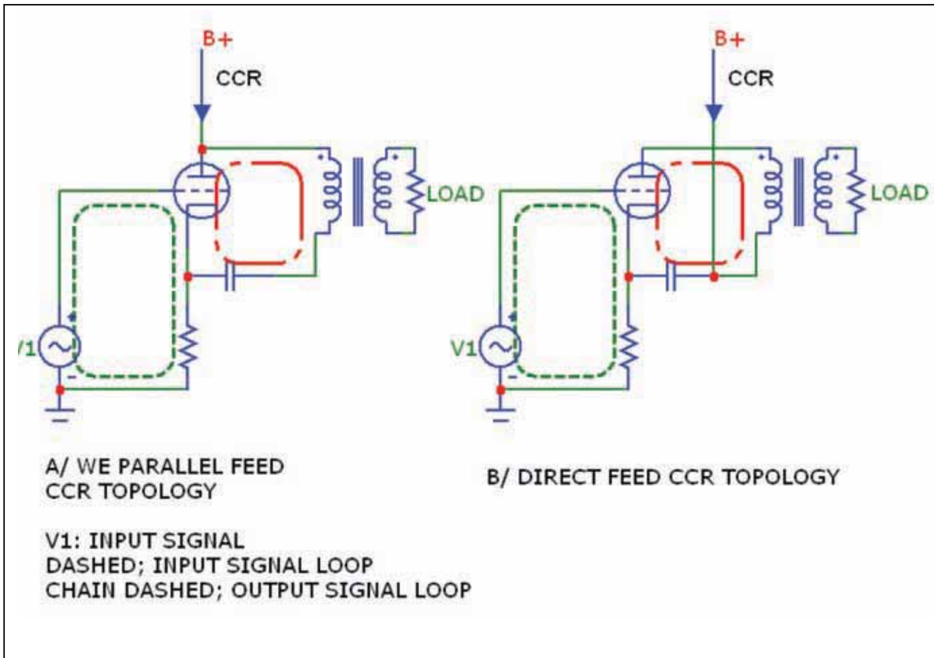


FIGURE 5: Parallel and direct-feed single-ended topology with CCR technology.

same level of signal isolation and noise attenuation from the PSU that a CCR can, both at the low-frequency end due to limited reactance and at the high-frequency end due to shunt capacitance.

It is worth noting that when this WE topology was conceived, the CCR would have been tube based that—in requiring a much elevated B+ voltage together with added parts cost—would have had limited commercial viability. Now, with the advent of depletion-mode MOSFETs, this topology is not only attractive, but practical, too. My implementation uses direct-feed (**Fig. 5B**). I am considering making it switchable on the fly between parallel feed and direct feed for the sake of comparison and fun! Practically speaking, the switching is a simple matter of moving the CCR connection between ends of the output transformer primary, perhaps using wetted relays.

You may observe that both these topologies look like the Ultrapath topology trademarked by Jack Elliano[5]. The difference is that Ultrapath has no specific provision to isolate the signal from the power supply; Ultrapath relies solely on the PSU bypass capacitor. It is also worth noting that a cathode feedback capacitor is not shown in either case and may not be necessary. It is possible, however, that audible levels of noise may be injected at the cathode. Fixing this by including a cathode bypass capacitor gets me back to having a big capacitor in the input signal loop, to avoid this situation, I advocate the use of grid bias combined with a coupling transformer to avoid this pitfall.

SINGLE-ENDED 50-300B AMPLIFIER

Figure 6 shows the topology of my recent direct-feed single-ended 50-300B project. It is extremely simple, particularly with respect to the signal paths because the power supply has been removed from the signal path by the CCRs. CCR power supply technology may be combined with grid bias for current gain/output stages or LED bias for voltage gain/drives stages to address both the signal path compromises identified at the beginning of this article. Accordingly, this design uses LED bias at the drive stage and grid bias at the output stage.

Moreover, a CCR power supply combined with grid bias allows you to set the quiescent current of the tube, and you can now vary the grid voltage to obtain the best sonic results *without changing the quiescent current*. The plate voltage will float to the necessary value for the tube to conduct the set current at the set grid voltage.

I took advantage of the CCR/grid bias arrangement to make changing the operating conditions between a 50 or a 300B a simple matter of turning a switch. I adjusted the grid bias voltage values for the 50 and 300B such that the distortion residual (monitored on a scope using a HP339a analyzer) was cleanly 2nd harmonic across the full dynamic range of the amplifier. The filament current draws of the 50 and the 300B are very nearly equal, so I used current regulation for the filament also, thereby avoiding the need to change the filament supply setting when changing tube types. This design sounds excellent, more open, and able to resolve far more deeply than my previous designs.

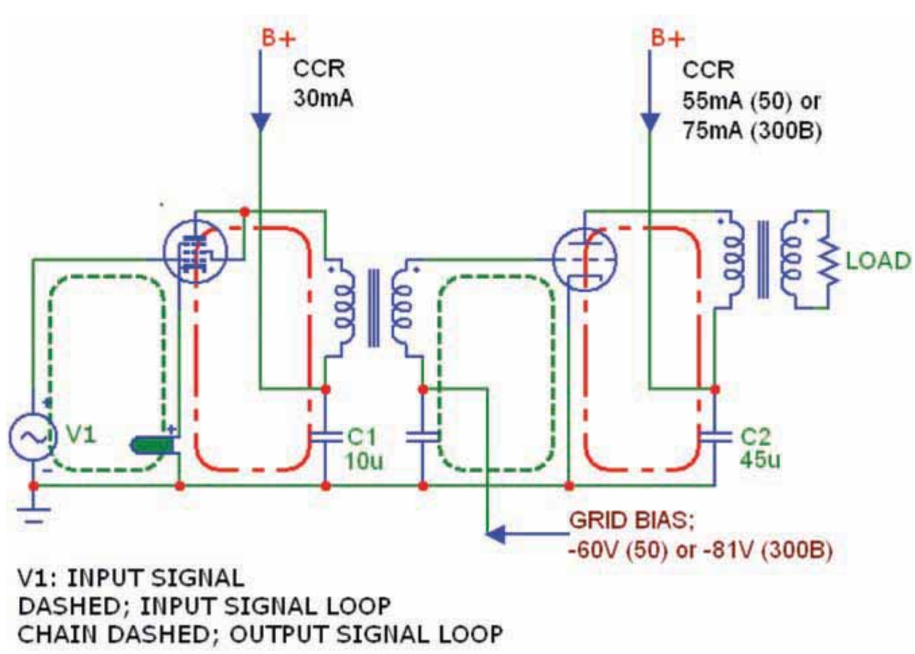


FIGURE 6: SE 50-300B topology showing signal loops with CCR technology.

PUSH-PULL IMPLEMENTATION

Figure 7 shows two push-pull topologies that use CCR technology. In **Fig. 7A**, the CCR is located in the plate circuit, so there is no cathode coupling. The circuit exhibits current balance but not current and voltage balance.

Taking an extreme case, if you apply the input to only one grid, the result will be gross distortion. You can do much better if you place the CCR in the cathode circuit (**Fig. 7B**). The circuit is now a long-tailed pair that is completely self balancing, fully compensating for any imbalance in the input signals.

PUSH-PULL CLASS A 6AS7G AMPLIFIER

The first approach I came up with was the "Current Balanced Push-Pull" amplifier, published in the May 2006 *audioXpress*. When I produced the current balanced amplifier, I was primarily exploring the potential of inexpensive toroidal power transformers as output transformers. The result was one of the best-sounding amplifiers I have built or heard.

This implementation originally used a simple (single) MOSFET type CCR located in the cathode of each output triode to ensure near perfect DC current balance to avoid DC saturation of the toroidal output transformer. The cathodes are coupled together with a capacitor to obtain perfect signal balance in the output tubes and thus true Class A. I dubbed this arrangement a "Power Long Tailed Pair."

Because the push-pull signal path loop impedance is higher than the cathode resistance of the triodes (refer to the chain-dashed loop in **Fig. 7**), the capacitor does not need to be in the range >100µF; in fact, in this case it is a 10µF film type. The effectiveness of the CCR technology is revealed by the fact the output and drive stages share a common supply. I and my friend, bassist John Dahlman, found it difficult to distinguish whether a PSU bypass capacitor was present, suggesting that the true Class A push-pull behavior made possible using CCR technology frees us from PSU bypass capacitor quality concerns. I recently updated this design, replacing the simple MOSFET CCRs with cascode CCRs (**Fig. 8**).

PUSH-PULL, THE NEXT LEVEL?

Many years ago, John Camille developed a single-ended 845 amplifier. He courageously shunt regulated the B+ supply using another 845 controlled by the signal via an op amp.

I am certain that well-implemented shunt voltage regulation is superior to series voltage regulation. For one thing, the shunt may be fed using a CCR, thereby isolating the shunt signal loop from the PSU. Another characteristic of the shunt regulator is that it can both feed and absorb current, which is perfect for output stages. However, John's design and, until recently, other implementations I have seen are asymmetrical; the shunt circuit does not complement the signal circuit.

I am beginning to wonder whether true Class A push-pull may actually be superior to single-ended! I suspect that many so-called Class A push-pull amplifiers actually cross into Class AB during more of the program material than is generally recognized, with the result that not only is the PSU modulated audibly, but also the output resistance of the amplifier is continuously switching. In past days, 20dB of negative feedback would most likely have swamped this issue (and the music), but with "modern" zero feedback triode designs, I suggest that this issue might horribly compromise the sonic results. Whether this is valid, true Class A push-pull opens up the possibility of a self-shunt regulating amplifier.

The point I am making about a true Class A push-pull amplifier is that given that it is fed via a CCR (preferably in the cathodes to ensure near perfect signal current and voltage balance), then it is self-shunt regulating (**Fig. 7B**). And so for me, the next level is to take what I have started with—the 6AS7G output and drive stages—and apply this self shunt-regulation, true Class A push-pull technology to all the stages.

In fact, Kevin Carter of K&K Audio is doing this and his GM70 PP design is the best-sounding amplifier I have yet heard. Furthermore, Kevin has nice PCBs available for building CCRs.

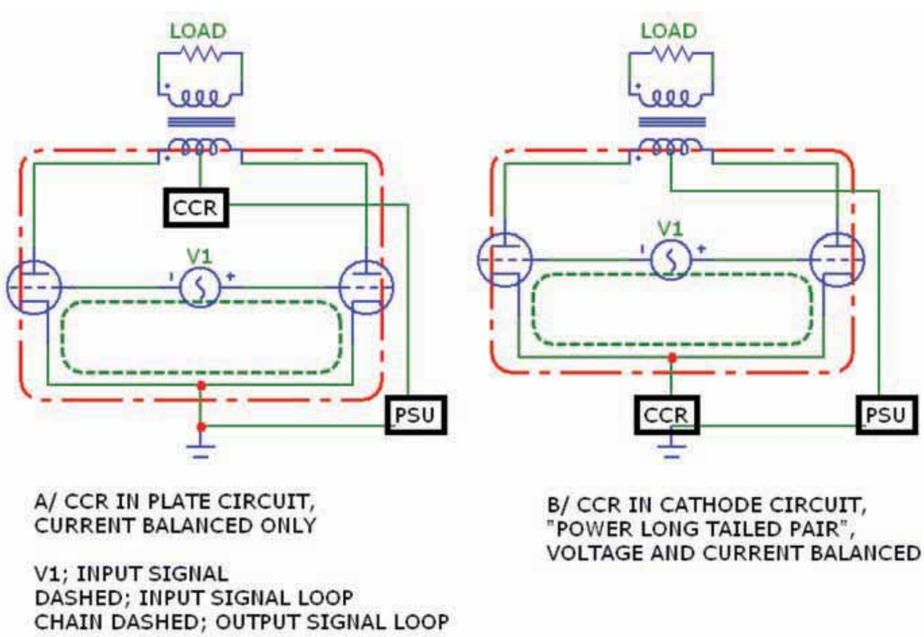


FIGURE 7: Class A PP topology showing signal loops with CCR technology.

CCR THERMAL ISSUES

After a year or so, my 6AS7G PP amplifier failed due to overheating of the DN2540 MOSFETs used in the CCRs. The current levels went far out of specification resulting in the amp going from extremely musical to horrible! Part of the problem was due to inadequate ventilation.

However, I had been considering replacing the simple CCRs with cascode units for a while and this was the opportunity! Referring back to **Fig. 2**, you will see that in this topology, the V_{DS} of the critical control MOSFET M1 is limited by the V_{GS} of the cascode M2. Clearly this topology has the further

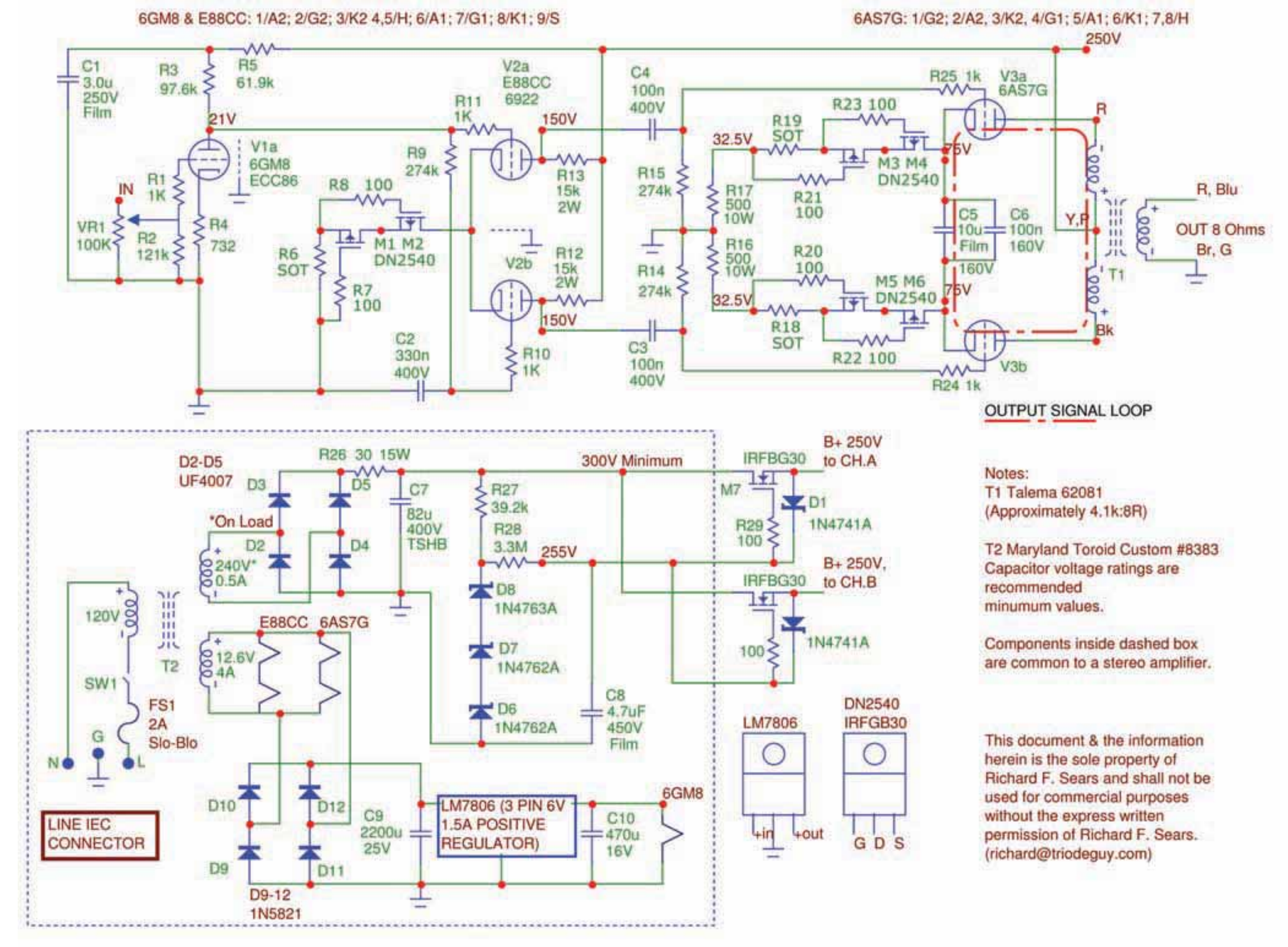


FIGURE 8: 6AS7 current balanced PP amp.

advantage of causing very low heat dissipation of the critical control MOSFET M1. If the voltage drop is large, I take some of the thermal load off the CCR by putting an appropriate value of power resistor in series with it.

In this case, I spread the 6AS7G cathode voltage 50/50 between the CCRs and resistors. I mount the two MOSFETs back-to-back on a single heatsink; however, I now use larger heatsinks than I think are necessary and ensure that they are in free air. Moreover, given that the MOSFETs are back-to-back, I use two mica insulators and no thermal grease on M1 to reduce the heat soak from M2 and a single mica washer with thermal grease on M2. So far, this is working well; the DC current in the output tube push-pull sections has remained stable and the current balance between the push-pull sections remains better than 0.5mA.

MISCELLANEOUS

Other possible applications of the depletion MOSFET two-terminal CCR technology are:

1. Norton DC signal level shifter. Sometimes it is desirable to shift the DC level of the signal, for example, when DC coupling. **Figure 9** shows a Norton level shifter that simply superimposes a clean DC current on the signal. The DC current flows through a resistor interposed between the plate of the first stage and the grid of the second stage causing a DC potential difference that can be arranged to match the potential difference between the plate and the grid.

Because the CCR has an impedance of 1.5MΩ or higher, it adds little load to the previous stage. The operating conditions of the circuit need to be extremely stable (as with all D-coupled circuits), so PSU voltage regulation is a good idea. Also, the value of the interposed resistor R will interact with the Miller capacitance of the second stage. All in all, I think this device is mostly of curiosity value, especially given that interstage transformer coupling sounds so excellent. Still, you may find a use for it!

2. Precision variable ultra low-noise DC voltage reference. I still use voltage regulation in some areas; for example, my SE 50-300B design uses MOSFET series regulation ahead of the CCRs. I wanted a simple way to adjust the output voltages, so zener diodes were not the best

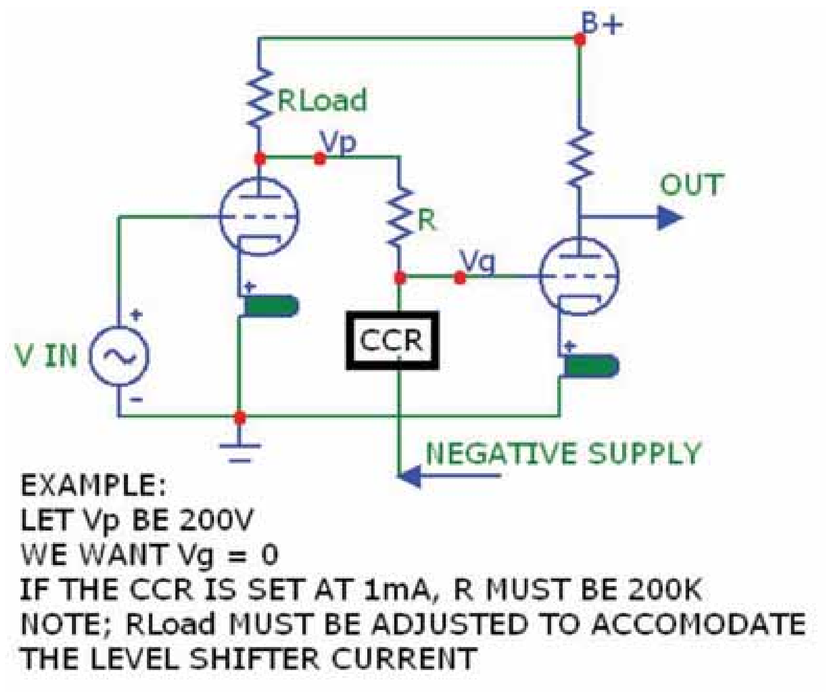


FIGURE 9: DC coupling using a CCR Norton level shifter.

choice for the gate voltage reference. Because the DN2540 cascode CCR is so extremely stable, I simply built an adjustable one (using a pot in place of the SOT resistor in **Fig. 2**) feeding current through a thermally stable metal film resistor (having an adequate voltage rating) to obtain a precise, ultra clean reference voltage that does not drift around as components become warm (unlike a zener).

3. Tuning the load of a pentode or cascode to obtain the best sonic results and precisely define the driving impedance for a Lipshitz (or other) passive RIAA equalization network. This is a nice one that I almost hesitate to give away (**Fig. 10**).

I have found that a hybrid, JFET–triode cascode works and sounds extremely well for the front-end of a phono stage. So far, I am not alone in thinking this. However, the next issue is providing well-defined source impedance for the following Lipshitz (or other) passive RIAA equalization. The trick is to use a CCR to feed the current to the plate of the cascode; it only needs 15V to work.

Then put a resistor in parallel with the CCR to set the load. The resistor value may be adjusted to provide the best harmonic characteristics from the stage without changing the plate voltage or B+ voltage required unless the resistor is so small that it starts to conduct appreciable DC current; in that case, a CCR is redundant. You can use a pot for the resistor while experimenting; when the best value has been found, replace it with a fixed resistor.

Now, the plate load resistor value controls the cascode output impedance. The cascode plate resistance—in my designs, at least—will be around 3MΩ, so any variation in the cascode RP with age will have negligible impact on the accuracy of the equalization because 3MΩ is likely to be significantly greater than the value of the plate load resistor.

4. Shunt regulator current feed. If voltage regulation is desired—and it can be a superior way to implement ultra high-resolution, small-signal stages such as phonostages—then arguably the best way to do it is shunt regulation. **Figure 11** shows the topology of the stage specific shunt regulators I produced for my WE 416C MKII phono-stage. The shunt path is shown by the chain-dashed loop, and, again, the CCR isolates the shunt path completely from the PSU with sonic benefit.

Because this is a no-compromise design, I used a negative supply to permit the shunt triode to be directly across the phono-stage supply with nothing in the cathode circuit. Note: In this case, the shunt regulator is in the signal path; *a corollary to this is that an individual shunt regulator must be used for each stage to realize the resolution benefits of shunt regulation*. I have found that the effects of bypass capacitors in my WE 416 phono stage are inaudible to me (I actually can switch them in and out of circuit to compare), so I am listening

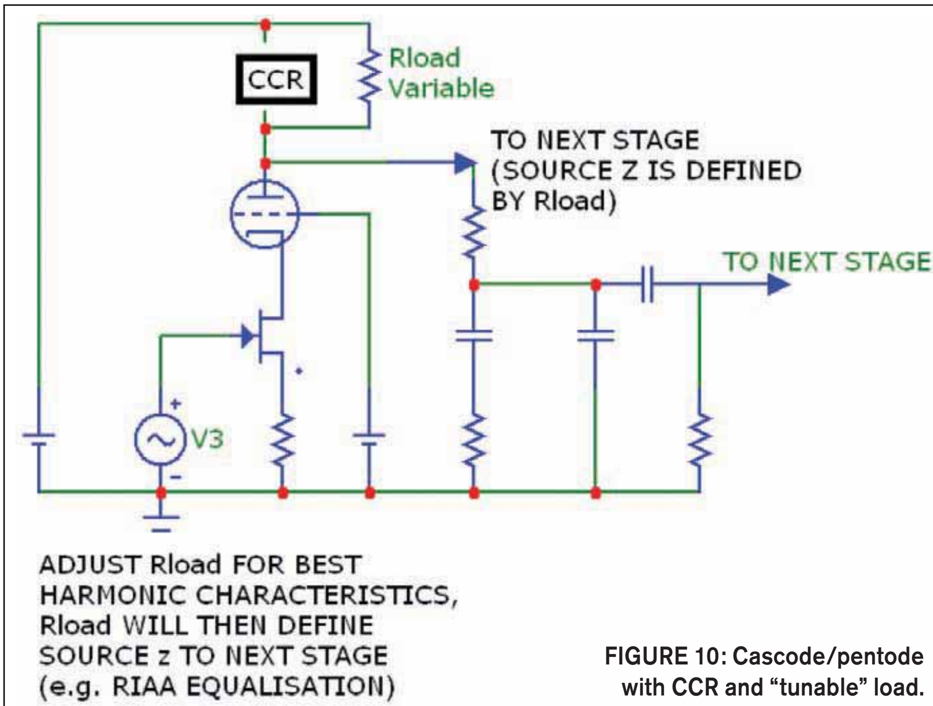


FIGURE 10: Cascode/pentode with CCR and "tunable" load.

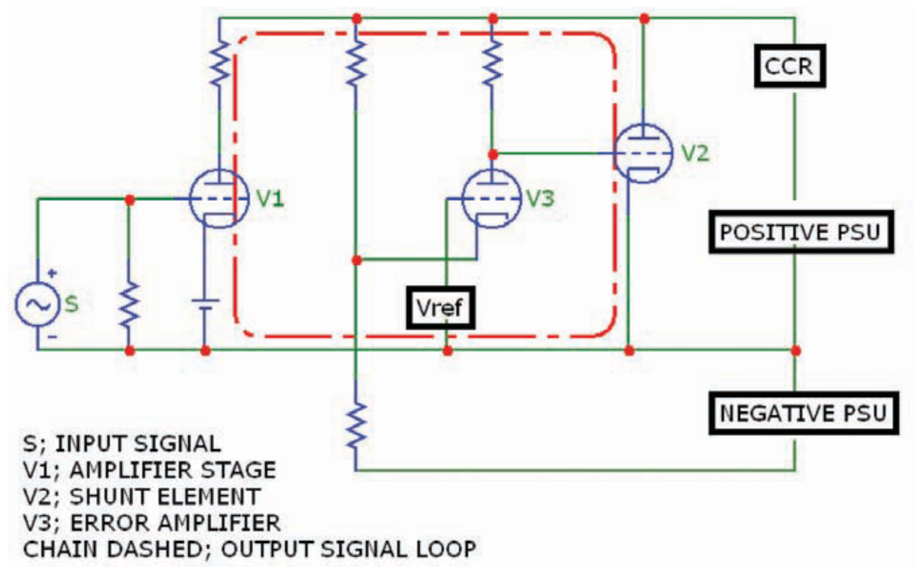


FIGURE 11: Shunt regulator with CCR feed.

to the regulators. This is the benefit of ensuring that a shunt regulator design is a match for the amplifier stage design, not a generic design. To reiterate, I suspect that the best shunt-regulated audio circuit is a long-tailed pair having a CCR as the tail.

CONCLUSION

My intention in writing this is to illustrate the potential for the thoughtful application of solid-state devices to more fully realize the sonic beauty of vacuum tubes than was possible without such devices. It is noteworthy that Western Electric had envisaged (maybe originated) the use of a CCR in the PSU current feed to a parallel feed, single-ended output stage, and, now, you can easily experiment with this concept.

I hope you find the ideas expressed in this article stimulating and applicable. I am a huge fan of experimentation; that is where the fun is so I encourage you to play! *aX*

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1. For a PSU source impedance of 4Ω, the bypass capacitor would need to be 4000µF to be effective down to 10Hz. Apart from not being practical at tube power supply voltage levels, such a large capacitor (or bank of capacitors) is likely to sound gruesome.
2. Walt Jung, letter to *audioXpress*, April 2009.
3. I distinguish grid bias from fixed bias. Grid bias is simply applying a bias voltage to the grid. Combining grid bias with fixing the plate voltage results in fixed bias. I set the grid voltage, set the current using a CCR, and let the plate voltage float.
4. Loop Distortion, Lynn Olson, www.nutshellhifi.com/library/Tube_Fest_Talk.html.
5. Ultrapath, Parallel Feed and Western Electric; Lynn Olson, *Vacuum Tube Valley*, Issue 16.

SOURCES

1. Source for CCR kits: K&K Audio (Kevin Carter), http://www.kandkaudio.com
2. Source for Supertex MOSFETS: Mouser Electronics, http://www.mouser.com
3. Source for IXYS MOSFETs: Arrow Electronics, http://www.arrow.com

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